Reviewed by Prof. Collis for Bull. J Hyg.

PUBLIC HEALTH BULLETIN

No. 221

ANTHRACO-SILICOSIS AMONG HARD COAL MINERS

U. S. PUBLIC HEALTH SERVICE
1798

U. S. TREASURY DEPARTMENT

PUBLIC HEALTH SERVICE

WASHINGTON, D. C.

U. S. TREASURY DEPARTMENT
PUBLIC HEALTH SERVICE

Public Health Bulletin No. 221
December 1935

ANTHRACO-SILICOSIS AMONG HARD COAL MINERS

From the Office of
INDUSTRIAL HYGIENE AND SANITATION
Surg. R. R. SAYERS, Medical Officer in Charge

Engineering Studies by
J. J. BLOOMFIELD, Sanitary Engineer
J. M. DALLAVALLE, Assistant Sanitary Engineer

Medical Studies by
R. R. JONES, Passed Assistant Surgeon
WALDEMAR C. DREESSEN, Passed Assistant Surgeon

Statistical Analysis by
DEAN K. BRUNDAGE, Statistician
ROLLO H. BRITTEN, Senior Statistician

(With sections on autopsy material by J. W. MILLER, Acting Assistant Surgeon, and on silica in the urine and in lung specimens by F. H. GOLDMAN Associate Chemist, U. S. Public Health Service)

PREPARED BY DIRECTION OF THE SURGEON GENERAL

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1936

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - Price 25 cents

CONTENTS

ILLUSTRATIONS

PLATES

ANTHRACO-SILICOSIS AMONG HARD COAL MINERS[1]

INTRODUCTION

In the spring of 1933 the Governor of Pennsylvania requested the United States Public Health Service to make a study of the nature and prevalence of chronic incapacitating miners' asthma. This action was taken on the recommendation of a commission appointed by Governor Pinchot in September 1932, to study certain phases of the problem associated with occupational diseases in Pennsylvania. Appreciating the lack of information on the subject, the Commission unanimously recommended that a survey be made by the Public Health Service with the cooperation of the employers and employees in the anthracite coal region (*1*).

Shortly after the receipt of this request for a survey, a representative of the Public Health Service conferred with officials of the departments of health, and of labor and industry of the State of Pennsylvania regarding the procedure to be followed, and, on May 15, 1933, a conference was held in Washington at which the anthracite coal operators, the United Mine Workers of America, the State of Pennsylvania, and the United States Public Health Service were represented. After the problem was discussed in some detail, a plan of study was outlined, and the responsibilities of each cooperating agency were determined. A memorandum covering the plan was signed by each representative present.

The mine operators agreed to furnish certain services to assist the field staff of the Public Health Service in its study of working conditions in the mines and the health of the employees. The representatives of the United Mine Workers of America assumed the responsibility for getting members to report for physical examination, and offered the assistance of interpreters, and other help in obtaining a detailed occupational history of each man examined. The Public Health Service agreed to furnish men trained for the tasks to which they were assigned. It was decided that all records obtained in the study were to become the property of the Public Health Service; in no instance would the physical examination findings for the individual be revealed to the man himself or to his employer.

The selection of mines to be studied was also made at this conference. A representative mine was selected in each of the three districts in which the anthracite coal field is divided by geological formation and

[1] Submitted for publication Mar. 27, 1935.

by method of mining (old, modern, and semimodern). One of the mines selected was in the northern, one in the southern, and one in the western middle area. It was agreed that all employees, including office, breaker, and other outside workers, as well as all underground employees, would be examined in each of the three mines selected for study.

Field work was started during the last week of May 1933, and was continued until the end of September 1933. During this period occupational and medical histories, and physical and roentgenological examinations were recorded on 2,711 men on the pay roll of the three mining companies. A record affording mortality data on the fathers of the men examined was also obtained. The results of the engineering, medical, and mortality investigations, and a general summary of the findings are presented in the pages which follow.

ACKNOWLEDGMENTS

The United States Public Health Service wishes to express its appreciation of the work of all who cooperated in the study. The anthracite coal operators and the United Mine Workers of America rendered invaluable assistance throughout the course of the study. The various State organizations granted access to records and the help of institutional staff as well as the use of equipment when needed. The State departments of labor and industry, and of health, extended every courtesy and contributed important data. The whole report, in fact, is the result of a cooperative undertaking so extensive that space is not available for mentioning by name all those who took part in it.

I. SUMMARY AND CONCLUSIONS

The term anthraco-silicosis as used in this report is a descriptive title for the form of pneumoconiosis commonly called miners' asthma. It is a chronic disease due to breathing air containing dust generated in the various processes involved in the mining and preparation of anthracite coal. It is characterized anatomically by generalized fibrotic changes throughout both lungs with the presence of excessive amounts of carbonaceous and siliceous material, usually by compensating emphysema, and often by cardiac changes in the later stages of the disease. The chief subjective symptoms found in the early stages were shortness of breath, cough, and pain in the chest; later, weakness and hemoptysis were frequently mentioned. The most common objective symptoms were dypsnea, prolonged expiration, decreased chest expansion, clubbing of the fingers, change in breath sounds, altered fremitus, and impaired resonance. In the more advanced stages, or in cases complicated by infection, persistent rales, cardiac impairment, loss of weight, and cyanosis were often seen, and usually there was more pulmonary infection, and moderate or marked

decreased capacity for work. Lung changes, general in distribution, often with more or less fixation of the diaphragm, were shown by fluoroscopic and X-ray film examination.

Diagnosis was based on three important classes of findings: (*a*) histories—occupational and past medical; (*b*) clinical examination, symptoms, and physical findings; and (*c*) X-ray examination, fluoroscopic and film. For a definite diagnosis of anthraco-silicosis, information from all three sources is required. In determining the role played by specific infection, laboratory examination should supplement the knowledge gained from the three sources mentioned. In certain border-line cases, repeated examinations may be necessary. A post-mortem diagnosis should be based on the results of pathological and chemical examination of the lungs. A complete diagnosis of anthraco-silicosis includes a statement of any associated complications, and of the extent and cause of permanent decreased capacity for work if such is shown.

Of the various contributory factors observed in the development, course, and final effect of the disease, pulmonary infection and cardiac impairment appeared to be the most important, especially in the advanced stages of the disease.

These conclusions in regard to the nature and development of the disease were based on the examination of 2,711 men (about 96 percent of the number on the pay roll of the three representative anthracite coal mining companies studied), on the findings for 135 disabled ex-miners who were hospitalized for observation, and on a smaller group examined in a State tuberculosis sanitarium.

The coal-mining employees were grouped occupationally, largely in accordance with the proportion of free silica found in the dust to which they were exposed.

No cases of anthraco-silicosis were found in a control group composed of hard-coal mining employees whose dust exposure averaged less than 5 million particles per cubic foot of air.

The prevalence of anthraco-silicosis among the entire group of employees was found to be about 23 percent.

Among all except rock workers, less than 2 percent of the men developed anthraco-silicosis when the duration of employment was less than 15 years, regardless of the amount of dust in the air.

Among men exposed 15 to 24 years to dust containing less than 5 percent free silica, 14 percent of those who had worked where the average dust count was 100 to 199 million particles per cubic foot, 29 percent of those exposed to 200 to 299 million particles, and 58 percent of the men who had worked for this period in more than 300 million particles per cubic foot, developed anthraco-silicosis.

Among men employed for more than 25 years in dust containing less than 5 percent free silica, the proportion of persons found with

anthraco-silicosis under different concentrations of dust was as follows: 5 to 99 million particles, 7 percent; 100 to 199 million particles, 54 percent; 200 to 299 million particles, 71 percent; 300 or more million particles per cubic foot, 89 percent.

With the exception of miners, their helpers, and rock workers, about 25 percent of all the men employed underground developed anthraco-silicosis after a working period of more than 25 years. This group was exposed to dust having a quartz content of about 13 percent.

The prevalence of anthraco-silicosis among persons who had been exposed for more than 2 or 3 years to dust of which about 35 percent was free silica, varied from 10 percent among those who had worked in concentrations of less than 200 million particles per cubic foot for less than 15 years, to 92 percent among those who had been employed for more than 25 years in dust concentrations exceeding 300 million particles per cubic foot, more than two or three years of which time was spent in rock work.

Age per se appeared to play a minor role in the development of anthraco-silicosis.

Analysis of the data for the purpose of determining safe limits of dust exposure indicated that employment in an atmosphere containing less than 50 million dust particles per cubic foot would produce a negligible number of cases of anthraco-silicosis when the quartz content of the dust was less than 5 percent. In the gangways where the silica content of the dust was about 13 percent, a safe limit appeared to be 10 to 15 million particles per cubic foot. The limit of toleration for rock workers was set tentatively at 5 to 10 million particles per cubic foot of air.

Pulmonary infection increased with length of service more rapidly among the men in the haulageways than in the control group, and much more rapidly among the regular miners. The highest rates of pulmonary infection, however, were found among the rock workers of more than 15 years' service.

The prevalence of pulmonary tuberculosis among the hard-coal mining employees at ages below 35 was slightly less than that found through studies of tuberculosis among male adults in the general population of the country. In the age group 35 to 44, however, the prevalence of tuberculosis was about twice, at ages 45 to 54 about 5 times, and for the ages above 55 it was about 10 times the rate found in the general population.

The highest prevalence of clinical pulmonary tuberculosis occurred among the rock workers (men who had been employed in rock loading or rock extraction for more than 2 or 3 years). After 20 years' service of which more than 2 or 3 years were in rock work, 37 percent presented evidence of pulmonary tuberculosis.

In a group of 135 completely disabled former anthracite workers, which did not include any known cases of tuberculosis, 10 percent proved positive for pulmonary tuberculosis.

Pulmonary infection (tuberculous and nontuberculous) was found among 58 percent of the employed men having early anthraco-silicosis, and in 92 percent of the workers in the more advanced stages.

Clinical pulmonary tuberculosis was diagnosed in 15 percent of those with early anthraco-silicosis, and in 43 percent of those in the more advanced stages.

In all groups combined with the exception of the control group, about 20 percent of the nontuberculous workers were diagnosed as having some respiratory disease other than tuberculosis. In the control group only 6 percent had nontuberculous respiratory disease.

In the control group less than 2 percent were found with moderate or marked physical impairment causing decreased capacity for work as compared with about 10 percent among the regular miners, and with approximately 13 percent among the rock workers. With the exception of the rock workers, no group showed moderate or marked physical impairment in excess of that found among the controls when the period of employment was less than 20 years. However, an excess in the prevalence of slight impairment was found among the regular miners and among others exposed to dust containing less than 5 percent free silica when they had worked from 10 to 20 years in atmospheres containing more than 100 million particles per cubic foot.

The correlations between exposure to dust and the evidence of constitutional changes left little doubt as to the etiological significance of the dust in the air breathed. Like correlations were found between the silica exposure and the extent of pulmonary changes.

Mortality from respiratory diseases was found to be much greater among anthracite workers than in the general adult male population of the country. The data indicated that underground work in the absence of dust did not predispose to fatal attacks of respiratory disease.

Several dust-control measures were employed in the mines studied. As shown in table 19, the dust hazard may be greatly lessened, and in some instances adequately controlled by the extension of these methods, viz, by:

(*a*) Provision for adequate ventilation of all work places.

(*b*) Employment of wet methods in all mechanical drilling operations.

(*c*) Thorough wetting of all coal and rock before loading.

(*d*) Substitution of mechanical loading for hand-loading methods wherever practicable.

(*e*) Insistence upon arrangements permitting the lapse of a period of time sufficient to reduce the dust concentration to a safe limit after firing charges.

(*f*) Use of wet methods in processing coal.

II. RECOMMENDATIONS

In addition to the methods of dust abatement already employed in some of the anthracite coal mines, certain other preventive methods have been found of practical value in other industries in which dust control is an important problem. For the sake of completeness a list of recommendations is given below regardless of whether some of them are already being carried out in certain mines.

1. Dust should be controlled at its point of generation so as to prevent it from reaching the breathing zone of the workers or contaminating the general air. Thorough wetting by water is a general method of dust control at the point of origin. Material abatement of dust in the working environment may be obtained by wet methods in almost all coal mining and processing operations.

Another method of controlling dust at its point of origin is by means of local exhaust ventilation. Dust-removal devices have been successfully employed in rock drilling operations in open excavations, and may prove feasible in drilling operations in anthracite mines. If this type of dust-removal device is employed, wet methods would still be necessary to allay the dust produced in the loading of coal and rock.

2. Adequate ventilation of all work places in the mines would tend to replace dusty air with clean air. Although satisfactory standards of air velocity in anthracite mines have not yet been established, an air movement of at least 50 feet per minute seems desirable from the standpoint of eliminating "dead-ends."

3. The more general use of mechanical methods of loading coal would contribute substantially to the solution of the dust problem. A dust count of less than 30 million particles per cubic foot of air was found associated with mechanical loading operations in one of the mines surveyed. This concentration is within the limits of toleration for the coal dust found in the mines studied.

4. Since blasting operations produce a large amount of dust, especially in dry mines, the firing of shots should be done only at the end of the shift.

5. An important source of silica dust in the haulageways was found to be sand used to prevent slipping of the transport motors. Thorough wetting of the roadbed would minimize the dust hazard in the haulageways.

6. Periodic studies of the condition of the working environment appear necessary to determine whether the control methods adopted

are really adequate. The work of inspection and review should be performed by persons trained for such duties.

7. In order to prevent the spread of respiratory infection, workers having active pulmonary tuberculosis should not be permitted to work underground or in dusty occupations above ground.

8. For the purpose of detecting cases of pulmonary tuberculosis and of anthraco-silicosis which have progressed to the point where further exposure to dust would jeopardize future working capacity, physical examinations including X-ray of the chest are necessary, not only of applicants for work, but also of all anthracite coal-mining employees annually. The periodic examination of all employees is required also for determining whether the preventive measures instituted for the control of dust are successful. For this purpose comparable records are needed to measure the degree of anthraco-silicosis and the extent of impairment of working capacity among the employees from year to year. Comparable records will not be obtained unless the periodic examinations are conducted in a standardized way, preferably by a permanent medical board composed of physicians specially trained and having adequate experience in the diagnosis of anthraco-silicosis and other diseases of the respiratory system.

9. It is recommended that consideration be given to the methods of medical control which have been found practical and effective in other industrial fields in which dust is a health problem, as in the Union of South Africa, Australia, and Ontario. Those recommended by the Special Industrial Disease Commission of Massachusetts in February 1934 are also worthy of study.

A situation which perhaps most closely parallels that in the Pennsylvania anthracite coal fields from the standpoints of area involved and number of employees is found in the gold mines of South Africa. The most important provisions for controlling the dust there are the use of water sprays, wet drilling, special rules in regard to blasting, adequate ventilation, and inspection which includes dust sampling.

A miners' phthisis medical bureau was created several years ago to examine and certify all white applicants for underground work to be physically fit and free from any disease of the respiratory organs; to examine all white miners every 6 months for the purpose of determining and reporting all cases of simple silicosis, tuberculosis with silicosis, and simple tuberculosis; and to examine at intervals, when necessary, those suspended from employment on account of silicosis and those awarded compensation to determine whether or not the disease had progressed to a further stage. The physical condition of native laborers is also checked periodically. Stethoscopic and radiographic examinations are made annually of all natives who have worked in any mine for 5 years or more. Any native suspected by a mine medical officer of having silicosis or tuberculosis is referred to

the medical bureau for examination. A medical board of appeal was established in 1925 to which cases are referred when there is dissatisfaction with the decision of the medical bureau.

10. In the control of dust hazards there is no single measure applicable to all dusty operations and processes. All the means of prevention mentioned must be practiced to insure success in the solution of the problem.

III. THE WORKING ENVIRONMENT

An important procedure in the search for major factors in the causation of disease suspected of occupational etiology is a detailed investigation of the conditions under which the work is performed. The present investigation of working environment consists of an analysis of the various operations and activities involved in the mining and preparation of coal in three representative anthracite mines, time studies of certain operations, and the sampling and analysis of the atmospheric dust. In addition, certain data were obtained on temperature, humidity, and air movement in the mines.

1. METHODS AND INSTRUMENTS USED IN THE STUDY

Knowledge of the hazards associated with each occupation and the number so exposed was obtained from an occupational analysis made during the first inspection of activities below and above ground. At this time certain typical places were selected for more detailed studies of the working environment.

In work on an occupational dust problem, the amount of dust suspended in the air breathed, the nature of the dust, and the duration of exposure should be determined. In the present study the last-mentioned factor was obtained from an occupational history of each worker. In measuring the quantity of dust to which each person was exposed, dust samples were obtained with the Greenburg-Smith impinger apparatus, and were analyzed by the standard Public Health Service technique (*2*). In determining the composition of the dusts, samples of settled dust were collected at the breathing level and were subjected to a combined chemical and petrographic examination (*3*). Consideration was given to the size of the dust particles suspended in the working atmosphere because not all dust particles are of a size capable of gaining access to the lungs. It has been shown, however, (*4*) that a large proportion of industrial dust particles suspended in the air are less than 3 microns in longest dimension, a size permitting access to the lung tissue. A large number of samples of atmospheric dust were obtained with the Owens apparatus (*5*) and were examined for particle size in accordance with the method described by Chamot (*6*). Photomicrographs were made of some of these samples.

Dust samples were obtained representative of each activity in a number of dusty occupations in order to make possible a determination of the quantity of dust which each activity contributed to the sum total of occupational exposure. In this way the average dust exposure for each numerically important occupational group could be estimated. Time studies were made of the chief occupations, and supplemental information was obtained from the workers and the records of the companies in question. With detailed information of this sort it was possible to evaluate the importance from a health standpoint of each activity involved in a given occupation.

In addition, ventilation readings were made at the working places with the aid of the standard sling psychrometer and the Kata thermometer.

2. THE MINING AND PREPARATION OF ANTHRACITE COAL [2]

GEOGRAPHY OF THE ANTHRACITE FIELD

The anthracite coal region of northeastern Pennsylvania occupies an area of almost 500 square miles. It consists of four comparatively narrow fields lying in a northeasterly to southwesterly direction, extending from Forest City at one extremity to Dauphin at the other (fig. 1). The areas of these fields are as follows:

	Square miles
Northern field	176
Eastern middle field	33
Western middle field	94
Southern field	181
Total	484

Frequently, for trade purposes, the anthracite fields are divided into three regions and are referred to as the Wyoming, Lehigh, and Schuylkill regions. The Wyoming region comprises the northern field; the Lehigh embraces the eastern middle field; and the Schuylkill includes the western middle and southern fields.

The coal beds of the northern or Wyoming field are flat, except at the outcrops on either side of the basin containing them. At these places the veins are pitched at angles ranging from 10 to approximately 50 degrees. The general contours of the beds in this region are indicated in figure 2. In contrast to the comparative flatness of the beds in the northern field, those of the southern are characterized by steeply pitched veins, with many faults and outcroppings (fig. 3). Mining operations in the latter field are frequently conducted in seams which are pitched from 60 to 70 degrees. The western middle field

[2] We are indebted for much of the descriptive material pertaining to the mining and preparation of coal to the Hudson Coal Co., which furnished us with a copy of its book, The Story of Anthracite, and permitted reproduction of many of the illustrations contained in this book.

contains beds which are similar to those in the northern field, but more steeply pitched at the outcrops, while those of the eastern middle field resemble, for the most part, those of the southern.

The number and thickness of the veins vary in each field. In some coal basins only 6 seams are found while others contain as many as 14. Often the larger veins are split by an intrusion of rock into two or more separate seams.

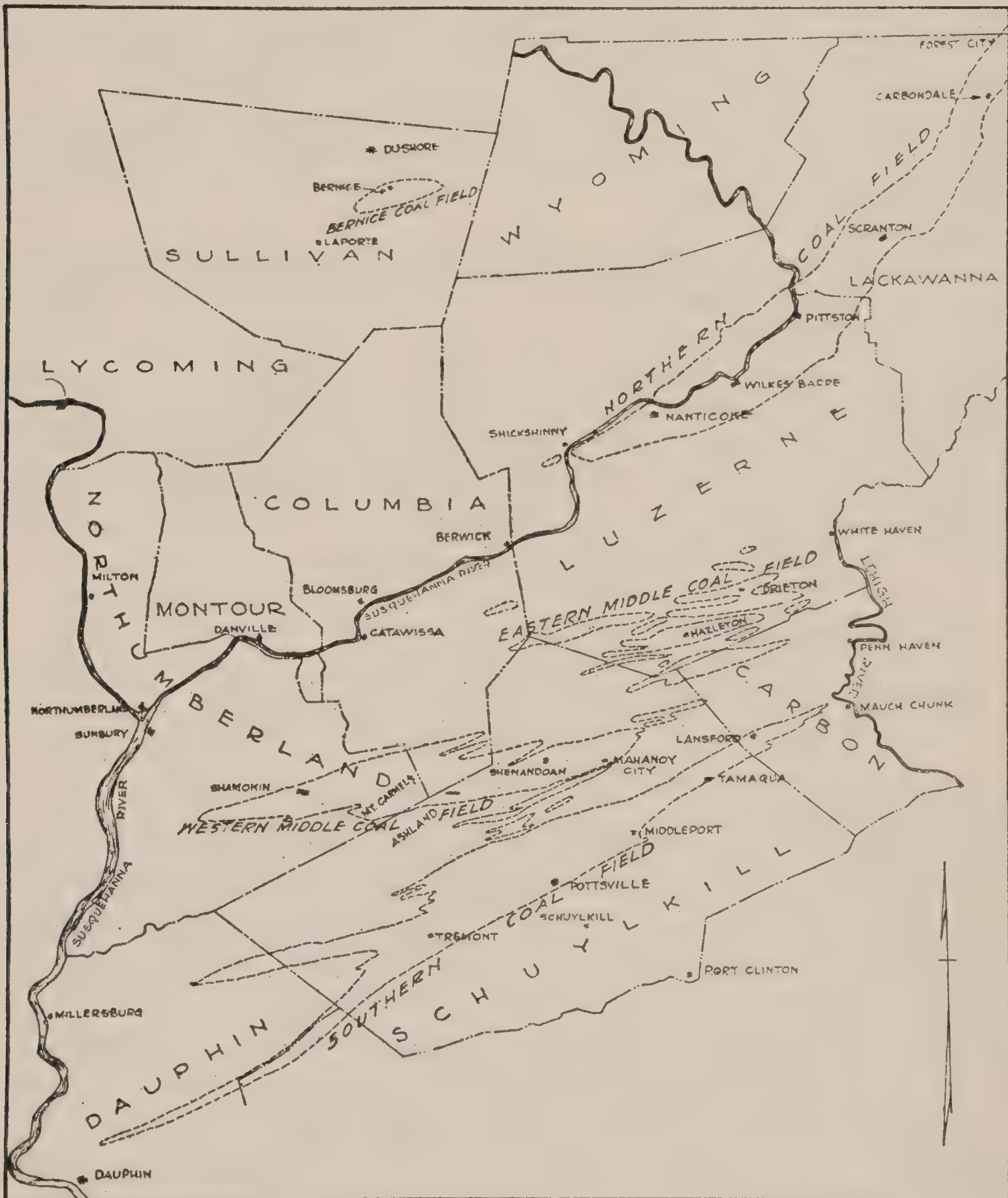


FIGURE 1.—The anthracite fields of northeastern Pennsylvania.

Mining operations are carried on in some seams which are only 2 feet in thickness, but the bulk of the coal is obtained from seams varying from 5 to 40, and in some cases as much as 100 feet thick. The southern field contains the thickest anthracite seam and the largest unmined reserves.

TYPES OF MINING

There are four principal methods of mining anthracite coal, as follows:

1. Chamber-and-pillar mining.
2. Chute or pitch mining.
3. Longwall mining.
4. Stripping.

Longwall and stripping methods were not included in the present study as they are limited in extent and employ only a small proportion of the anthracite mining population.

The methods and devices used in extracting anthracite coal are described briefly in the following paragraphs.

SHAFTS

According to the Hudson Coal Co. (Cf. The Story of Anthracite), by far the largest proportion of the anthracite output at present is brought to the surface by means of shafts. A typical shaft has two hoistways; one through which the loaded mine cars are brought to the surface on cages; the other in which empty cars are lowered in the same manner. A shaft "cage" consists essentially of a platform with an iron guard rail and a steel canopy, the latter affording protection from debris and falling objects when men are raised and lowered in the shaft. The cages move along fixed guide rails and are provided with safety devices to prevent falling in case a hoisting cable breaks. The hoisting cables are strung over sheave wheels mounted on a substantial tower or derrick and are connected to large driving drums in an adjacent building.

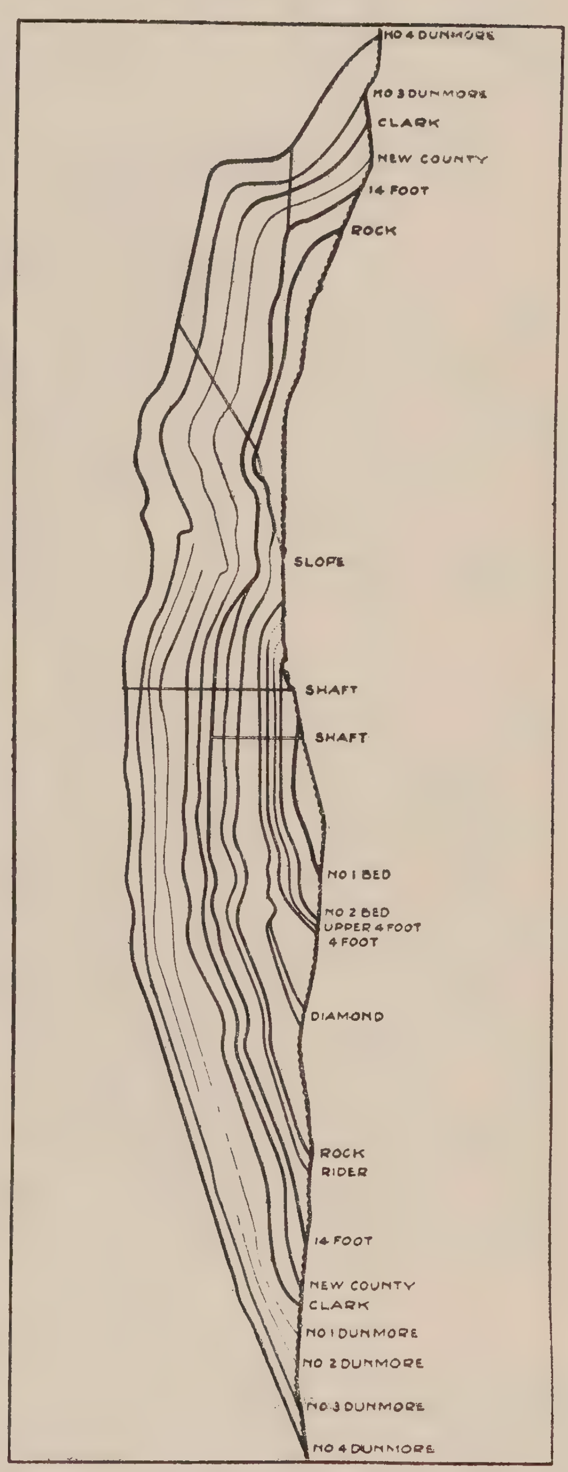


FIGURE 2.—Sketch showing section of anthracite beds in northern field.

When a shaft penetrates a coal seam which is being mined, a landing is provided from which the loaded mine cars are placed on the cage to be hoisted to the surface. At these places the miner is required to

139428—35——2

check or "peg" in before proceeding to his working place and to check out before going to the surface. A sump is generally provided at the bottom-most landing, near the foot of the shaft, into which all the water seeping into the mine is drained and pumped.

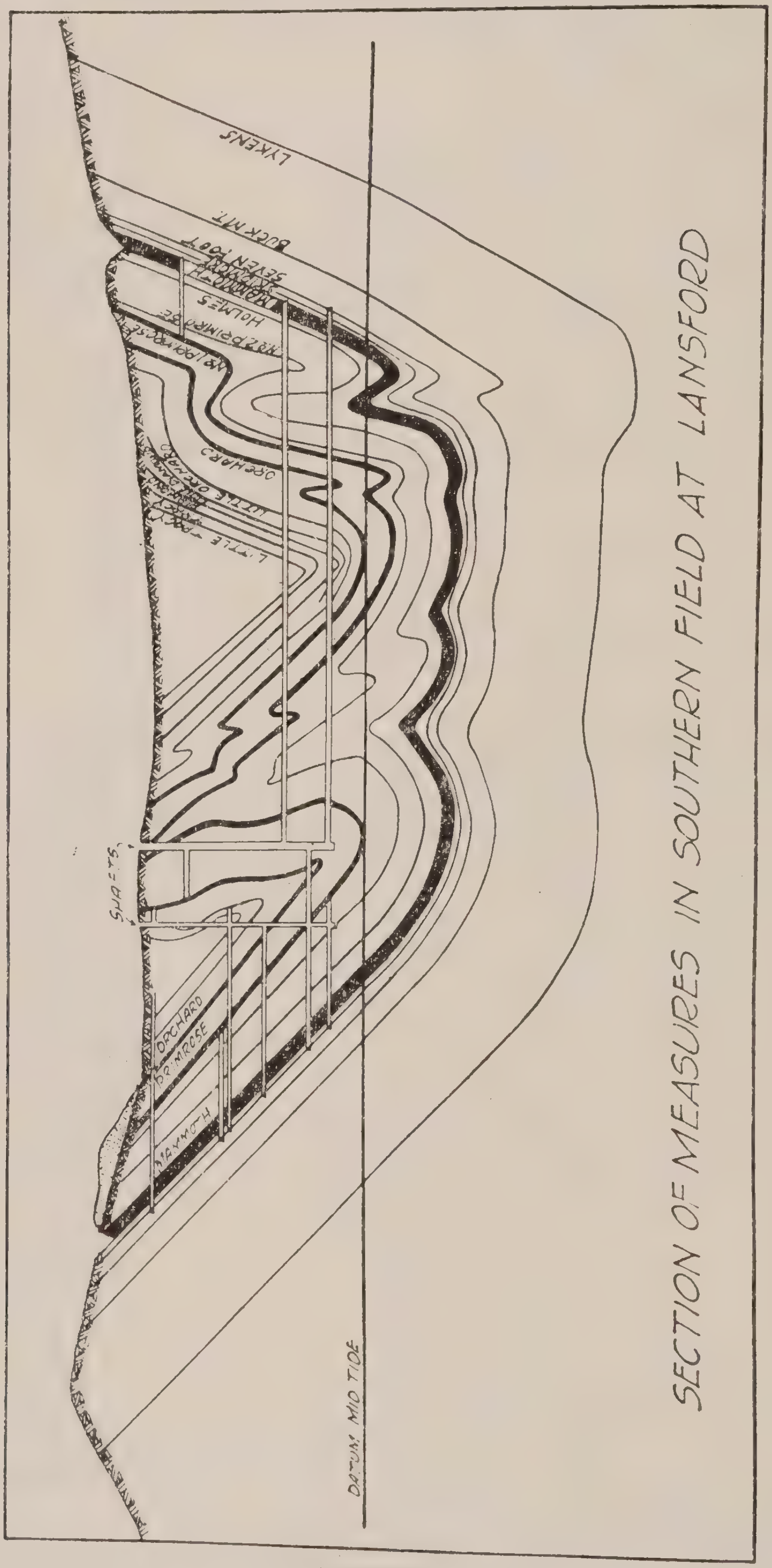


FIGURE 3.

GANGWAY OR OPENING WORK

From the shaft landings, gangways, or passages, are driven at regular intervals in rock or in coal, thus dividing the working area into

sections. The size of such gangways depends upon the nature of the material through which they are driven, but they are generally large enough to permit the passage of a mine car. As a rule they average 7 feet in height. Gangways are driven straight to reduce the resistance to the flow of air used for ventilation purposes, and are heavily timbered where the roof and walls are uncertain in strength. Timbering is done, not to support the overlying terrain, since no amount of timbering is capable of supporting such weight, but to hold the friable layers of coal and strata. Gangways are often driven through solid rock to connect coal seams which are inclined to its plane, and, in the case of pitch mining, are used to provide methods for obtaining coal from the overlying coal beds.

When a gangway is driven through a seam which pitches downward, it is referred to as a "slope." Slopes, however, may be driven through intervening strata from one coal bed to another, and may be entirely within the mine with no opening to the surface. In present-day terminology, slopes refer to inclines penetrating one or more coal seams up which the coal is transported. When the coal is transported downward, the slope is referred to as a "plane." Slopes and planes require special hoisting machinery for the transportation of mine cars.

Parallel to the main gangway through which the coal is transported to the shaft landing, at a distance of 30 to 40 feet, a return airway is driven. The fresh air entering the gangway is then separated from the return airway by a solid block of coal, except at intervals of 60 feet, as provided by law, where "cross-cuts" or "headings" are driven to facilitate the circulation of air as the workings are advanced. The return airway is generally laden with gas, dust, and smoke swept from the workings, and is never used for transportation purposes.

The main gangway usually divides or "splits" at a short distance from the shaft landing. In such cases the return airway may be circuited by brattices, or mine doors, to ventilate the workings in both tunnels. Return airways may be driven through intervening strata to upper levels, thus making a complete circuit through all the mine workings.

CHAMBER-AND-PILLAR MINING

Chamber-and-pillar mining is also called "room-and-pillar mining", and is generally used in the northern or Wyoming field, where the coal seams are comparatively flat. It is represented as Mine No. 1 in the data accompanying this report. Miners' working places, chambers or rooms, are driven along the gangways at specified intervals, and solid pillars of coal are left standing between them to support the roof. These pillars are from two-thirds to one and one-half times the width of the room or chamber, depending on the depth

below the surface. Larger pillars are left in the deeper coal beds in order to support the increased weight of the overlying strata. Such coal as has been left for "pillars" is not abandoned but is recovered in secondary mining operations called "robbing" which will be discussed later.

CHUTE OR PITCH MINING

In the southern field the coal seams are inclined to such a degree as to necessitate pitch mining. A gangway is driven, usually through solid rock, at the bottom of the seam, and an opening is made upward into the coal bed. The opening is timbered, and the base lined with metal which permits the extracted coal to descend by gravity to the gangway. When the opening has been driven for a specified length, it is branched into a V; each branch is then subdivided in the same manner until a gangway at a higher level is made. In this way diamond-shaped pillars of coal are left for the support of the roof. This sort of structure is known as a "battery." Batteries may be driven along the gangway at definite intervals, and are interconnected. A bulkhead is placed inside the battery at the bottom of the chute so that the battery may be allowed to fill with coal which is later drawn off into mine cars standing in the gangway (see fig. 4).

SPECIAL LOADING METHODS

In some mines the loading of coal has been mechanized. Three methods of mechanical loading are used in the anthracite field, viz, (*a*) the "buggy" method; (*b*) the scraper-loader method; and (*c*) the shaker-loader method.

A "buggy" is a very small mine car used to transport coal from the working face to the gangway where the coal is loaded into a standard mine car. The "buggy" is pushed by hand or is drawn by ropes and windlass from the gangway to the working face, and, when loaded usually moves to the gangway by gravity.

The scraper-loader method is adapted for large chambers and especially for robbing operations on level ground. A scraper-loader is similar to an old-fashioned snow plow, but operates with its wide end foremost (see fig. 5). It is attached by ropes to a hoist located in a cross-cut at the opposite side of the gangway. The hoist is equipped with two drums by means of which the scraper can be moved from the working place to the loading platform and back again. The miner sets the scraper so as to drag the coal to the mine car (see fig. 6). This has to be done in several steps when the mine car cannot be reached in one haul of the scraper.

Shaker-loaders or shaker-conveyors consist of sectional steel troughs which are fitted end to end as the working face progresses. The

trough is operated by a series of gears and eccentrics which convert the rotary motion of the electric motor into a reciprocating motion. A slow, forward movement is transmitted to the trough, followed by a quick, reversed motion which has the effect of "joggling" the coal along the trough (see fig. 7).

ROBBING

When the coal reserves have been depleted, an operation known as "secondary mining" or "robbing" is usually carried on. This operation consists of removing the coal left standing as pillars supporting the overlying strata. "Robbing" operations are conducted in accordance with a plan of procedure drawn up by the colliery engineers and under permits granted by the State department of mines. The removal of pillar coal does not differ from ordinary breast or chamber mining. Experienced miners, however, are required for such work.

TRANSPORTATION

All mines in the anthracite fields contain extensive track systems over which the loaded and empty trains of mine cars are moved. In chamber mining the track systems extend to all the miners' working places. Loaded cars are taken from the miners' chambers or from the gangways from where they originate, to sidings where a train of cars is made up and hauled to the shaft landing. Empty cars in turn are brought from the sidings to the miners' working places for loading. In pitch mining the cars are brought directly under the chutes, and are loaded by gravity.

Mine cars are hauled by electric locomotives or by mule teams. Mine locomotives may be either the storage battery or overhead trolley type. Some locomotives are equipped with cable drums for furnishing power beyond the limits of the trolley system.

The loaded mine cars are brought to the shaft landings in trains of 10 to 40 cars, and by special switching arrangements are pushed into the shaft cages in which they are hoisted to the surface. The empty cars brought down in the cage are pushed off by the loaded cars, and descend by gravity in a circular route to the main haulageway where they are made into trains and conveyed back to the workings.

MAINTENANCE

A large force of men is required to maintain the electrical, pumping, piping, and transportation services. The electrical services in a mine include lighting, wiring, motor installation and repair, and battery charging. Water pumps are maintained to remove the water which seeps into the mine. There are also piping systems for compressed air. Transportation maintenance consists of track repair

work, clearing drain ditches, and the removal of rock, coal, and waste material which accumulates along the main haulageways.

VENTILATION

In the mines under study, air movement is produced by large surface fans working from the suction or return-air side. Air enters the mines through one or more openings at the surface, and is sucked through various gangways and workings to the return airways. The latter are brought together into a single airway and connected to the fan.

The minimum air movement required by law in Pennsylvania anthracite mines is 200 cubic feet per man per minute. In some mines containing abnormal amounts of gas and abandoned workings to be ventilated, more than a million cubic feet of air per minute may be required.

The air flow in the mines is directed by means of brattices and doors. Diverted by the brattices, the air passes along the coal face, and enters the return airways through the cross-cuts. Brattices and mine doors are built by carpenters and masons. However, temporary brattices of wetted burlap are frequently put up by the miners (see fig. 8).

It is often impossible, especially in pitch mining, to secure adequate ventilation by ordinary means. In such cases compressed air is piped into the chamber. This method of ventilation is also adapted to mining operations at dead ends and in low seams.

SUPERINTENDENCE

The mine foreman has general supervision of all underground activities. Since it is impossible for him to supervise all the varied activities which take place in a mine, he maintains contact with the miners through sectional foremen who are responsible for the maintenance of scheduled output and all matters of safety in the sections of the mine under their jurisdiction. They also measure the yardage at stated intervals, and estimate the quantity of rock removed when this is necessary for computing the miners' pay. They countersign all orders for materials requested, and in many mines act as timekeepers.

A nightly inspection of all working places is made by fire bosses who test the chambers for gas and unsafe conditions. The miner is informed of the condition of his working place on arrival the following morning, and is cautioned about any existing danger.

CONVEYANCE OF RAW COAL TO THE BREAKER

The mine cars loaded with raw coal are conveyed to the breaker for cleaning and sizing. They are hauled to the highest part of the

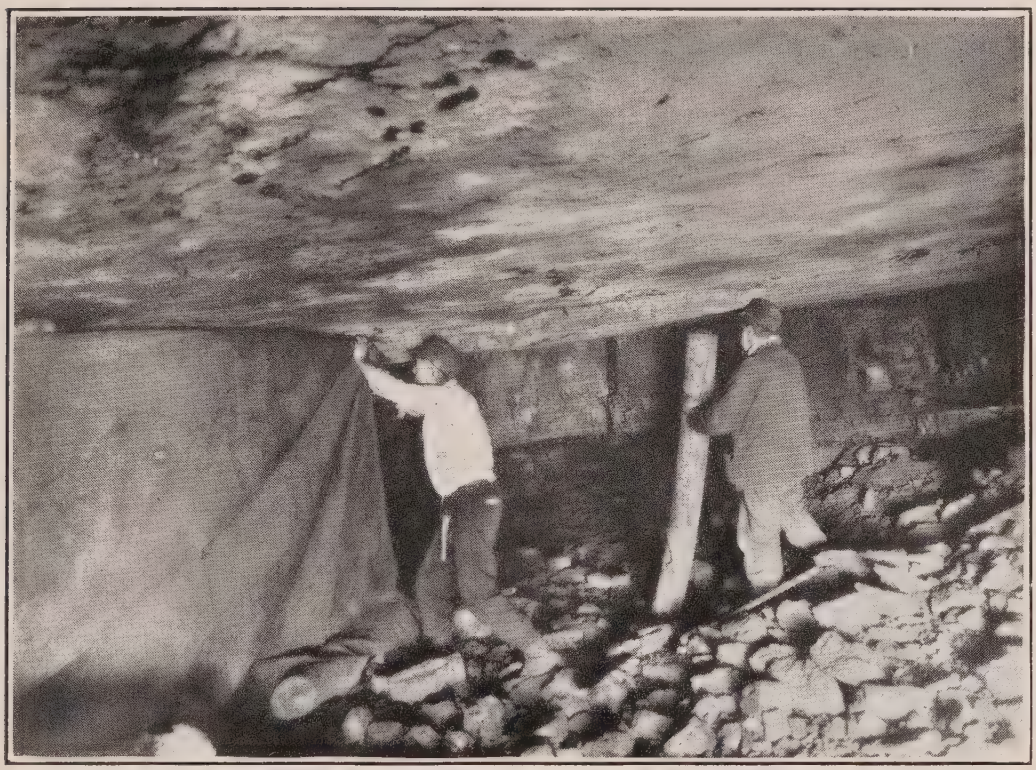


FIGURE 8.—PLACING CLOTH BRATTICE TO CHANGE AIR COURSE.

FIGURE 9.—PRIMARY SHAKING SCREEN.

breaker directly from the shaft tower if the breaker is located alongside, or by inclined planes connected to the shaft opening, or by separate elevators in the breaker. On reaching the top, the coal is dumped by releasing the car's flanged gate and by tilting the car into the gathering chute.

METHODS OF PROCESSING ANTHRACITE COAL

Two methods are in use for processing raw coal, one the dry method, and the other the wet. The dry method of treating coal is not extensively used at present, and is being gradually replaced by the wet method.

DRY BREAKER

In the dry method the coal is dumped into a chute equipped with a heavy screen similar to that shown in figure 9, through which pass the finer particles known as "fines." The larger lumps of coal and rock are conveyed to vibrating steel platforms having a reciprocating motion which causes the coal to move forward. The large pieces of coal are removed by platform men, and the lumps of coal containing rock are handled by "chippers" who use short, pick-like hammers to separate the rock from the coal. The rock-free coal is put back on the platform and conveyed to a crusher.

The finer lumps of coal may contain a considerable amount of rock and foreign matter which must be removed. The lumps are passed over a series of screens for sizing after which the separate sizes descend in vertical, spiral troughs, so adjusted and pitched that the heavier materials (rock) move to the edges and fall out. Not all of the rock is removed in this way, however, and the coal has to be picked over before it is passed to the storage bins. The work of removing rock and dull pieces of coal called "bone" is done by slate pickers who sit astride the chutes over which the coal descends.

WET BREAKER

In wet breakers the preliminary treatment of the raw coal is similar to that used in dry breakers. The large lumps of coal and rock are passed from the gathering chute to a platform, and separated. The coal is then wetted and screened, and conveyed to separators to remove the rock and foreign matter. Two types of separators are in general use, one of which depends on the impulse of water in small tanks which forces the lighter coal lumps to the surface where they are raked off. The other method makes use of a flotation principle: the coal is conveyed into a heavy suspension of sand in water in which the coal floats and the rock sinks. The operation is carried on in large cone-shaped tanks with special gate valves near the bottom from which the rock and slate can be removed. Cone separators

are so efficient as to eliminate the necessity for any hand picking. Wet breakers which do not have flotation methods for separating rock from coal require slate pickers, although not to the extent used in most dry breakers.

The economical disposal of coal fines constitutes an important problem in coal processing. Breaker fines are generally used for firing the boilers to furnish power for the mine machinery, but the amount of breaker fines produced is in excess of that consumed at the colliery. In rendering fines suitable for marketing, they must be carefully treated to insure purity. Impurities are removed on special jig tables which separate the heavier particles (rock) from the lighter (coal). Separators of the Dorr type are frequently used in connection with wet breakers to collect the fines and to clean the water for recirculation into the breaker.

LOADING OF RAILROAD CARS

Railroad cars or gondolas are placed beneath the coal bins for filling. Each car of coal is carefully checked for appearance, and samples are taken for physical and chemical analysis. Loaded cars which do not meet fixed standards of appearance and quality may be condemned, dumped into a special conveyor system, and returned to the breaker for reprocessing.

OTHER OUTSIDE ACTIVITIES

In addition to the large corps of men employed to repair and maintain equipment in the breaker, there are other groups of workers engaged in surface activities. A number of general laborers dispose of mine wastes at culm banks, maintain roads, unload cars of stripping coal, and do various odd jobs about the colliery. At collieries where coal is conveyed from distant shafts or stripping operations to the breaker, or where mine and breaker debris is hauled by steam locomotive, several locomotive engineers are employed. A considerable amount of repair work and the production of special parts is done by machinists employed above ground. The work of cleaning, charging, or fueling, and testing the miners' lamps is also done at the surface. Most of the clerical work, especially the preparation of time, salary, production, and shipping sheets, is performed in offices above ground.

The activities of a colliery are administered by a colliery superintendent who has charge of all inside and outside activities. Directly under him are the mine foreman and the outside foreman. The latter has charge of the breaker and all work done at the surface. In some of the smaller collieries, the mine superintendent acts both as inside and outside foreman, having only section and breaker bosses in direct contact with the workmen.

3. OCCUPATIONAL ANALYSIS AND DESCRIPTION OF CHIEF OCCUPATIONS

An occupational analysis of the workers employed at the three coal mines is given in tables 1 and 2. The number of men recorded for each occupation shown in the tables is a fair average of the number employed at these mines during the past few years.

TABLE 1.—*Occupational analysis of inside force of three anthracite coal mines*

Section and occupation	Number of men in mine no. —			
	1	2	3	Total
Cutting and loading:				
Contract miners and laborers	653	204	362	1,219
Company miners and laborers	106	1	23	130
Chute loaders	0	30	0	30
Starters	0	11	4	15
Scraper loaders	0	0	12	12
Scraper loader engineers	0	0	31	31
Shaker loaders	0	0	7	7
Total	759	246	439	1,444
Opening work:				
Tunnel and rock workers	0	88	7	95
Muckers and slatemen	21	14	0	35
Total	21	102	7	130
Ventilation:				
Fire bosses and helpers	11	6	0	17
Bratticemen, carpenters, and masons	26	6	23	55
Door tenders and doorboys	12	1	3	16
Total	49	13	26	88
Transportation:				
Loader and driver bosses	2	0	2	4
Station tenders	0	5	0	5
Shaft, slope, and plane tenders	63	3	20	86
Electric motormen, lokey engineers, polemen, and helpers	42	27	41	110
Patchers, car runners, conductors, and car haul operators	79	2	6	87
Mule drivers	45	15	22	82
Stablemen and helpers	3	1	2	6
Spraggers and car couplers	2	0	3	5
Total	236	53	96	385
Hoisting water:				
Pumpmen	4	0	7	11
Ditchmen	0	0	3	3
Total	4	0	10	14
Timbering: Timberers and helpers	14	61	19	94
Maintenance:				
Trackmen and helpers	17	12	2	31
Road cleaners	3	0	0	3
Shaftmen and helpers	8	3	0	11
Pipemen and helpers	4	0	0	4
Machinists	5	0	7	12
Electricians and helpers	1	3	10	14
Total	38	18	19	75
Superintendence:				
Foremen and assistant foremen	11	13	7	31
Clerks and timekeepers	1	1	0	2
Lampmen	0	1	1	2
Culm boss	1	0	0	1
Total	13	15	8	36
Grand total	1,134	508	624	2,266

TABLE 2.—*Occupational analysis of outside force of three anthracite coal mines*

Section and occupation	Number of men in mine no. —			
	1	2	3	Total
Transportation:				
Topmen, footmen, headmen, and helpers	8	1	0	9
Shaft, slope, and plane tenders	0	1	3	4
Car haul operators, runners, and shaft engineers	10	20	19	49
Slope and tower engineers	0	1	1	2
Car oilers	2	2	0	4
Locomotive engineers, firemen, and brakemen	0	16	4	20
Sandmen	0	1	0	1
Spraggers	6	0	0	6
Teamsters and truck drivers	0	1	1	2
Yardmen	0	2	0	2
Locomotive watchmen	0	2	0	2
Total	26	47	28	101
Maintenance:				
Timbermen	6	0	0	6
Carpenters and helpers	13	21	10	44
Welders	0	1	0	1
Machinists	5	26	14	45
Timber repairers	0	0	5	5
Blacksmiths and helpers	3	6	6	15
Trackmen and helpers	1	9	0	10
Electricians and helpers	0	3	6	9
Mule drivers	1	0	0	1
Mine car repairers	0	10	0	10
Fan engineers	4	0	0	4
Laborers	11	16	12	39
Total	44	92	53	189
Light, heat, and power:				
Ashmen	1	1	0	2
Firemen	11	6	0	17
Fuelmen	1	0	0	1
Breaker engineers	1	0	0	1
Powerhouse engineers	3	0	0	3
Total	17	7	0	24
Preparation:				
Dumpers	2	2	5	9
Plane tenders	0	4	0	4
Platform men	5	13	10	28
Chippers	2	0	0	2
Screen, elevator, and conveyor tenders	0	1	0	1
Jig tenders, cone attendants, and rock trappers	0	9	6	15
Slate pickers	40	17	0	57
Loaders, car runners, and cleaners	8	10	10	28
Chute bosses	4	0	0	4
Breaker bosses	1	0	0	1
Oilers	1	2	3	6
Machinists	0	0	11	11
Breaker cleaners and laborers	2	6	5	13
Repairmen	4	0	0	4
Ropemen, splicers, and helpers	0	3	0	3
Pumpmen and engineers	0	2	3	5
Concentrator and hydrotator attendants	0	5	1	6
Blue-coal attendant	1	0	0	1
Condemned coal dumpers	0	1	0	1
Coal inspectors	0	0	2	2
Total	70	75	56	201
Refuse:				
Rock-bank men	0	0	3	3
Bore hole attendant	1	0	0	1
Dorr thickener operator	0	1	0	1
Track shift operator	0	1	0	1
Loaders	0	1	0	1
Hoisting engineers, pumpmen, and plane tenders	0	1	0	1
Locomotive engineers, firemen, brakemen, and machinists	0	5	0	5
Dumpers and lorrie runners	0	4	2	6
Total	1	13	5	19
Superintendence:				
Superintendents, assistant superintendents, foremen, and assistant foremen	2	4	8	14

TABLE 2.—*Occupational analysis of outside force of three anthracite coal mines*—Con.

Section and occupation	Number of men in mine no. —			
	1	2	3	Total
Superintendence—Continued.				
Courthouse men	3	0	0	3
Clerks	6	6	4	16
Washhouse attendants	1	2	1	4
Watchmen	0	3	0	3
Lampmen	4	3	0	7
All other outside men	6	0	0	6
Total	22	18	13	53
Grand total	180	252	155	587

From these tables it is apparent that a great diversity of occupations is found in coal mining. The occupations may be classified in two broad groups, namely, those associated with the actual extraction of coal, and the indirect labor required for the mining operations. In mine no. 1, 58 percent of the total number of employees were engaged in cutting and loading coal, in mine no. 2, 38 percent, and in mine no. 3, 57 percent were thus employed. The lower percentage found in mine no. 2 was due to the considerable tonnage obtained from stripping operations handled by the outside force which obviously necessitated a smaller number of miners and loaders inside. In the three mines as a whole, slightly more than one-half (53 percent) of the total force was engaged directly in getting out coal. In the cutting and loading operations most of the dust in the mines is generated. Accordingly, chief interest is with those occupations listed in the cutting and loading section. About half of the atmospheric dust samples were obtained on this important group of workers.

In order to show the various duties involved in different occupations, it seems appropriate to give brief definitions of the more important occupations in the industry. Such a list of definitions follows:

Inside Force

CUTTING AND LOADING SECTION

The duties of a *contract miner* comprise drilling holes either with a jack-hammer (see Fig. 10) or with a hand drill (see fig. 11) in the face or breast of the coal, and charging the holes with explosive. After firing, he assists in the removal of the coal from the face or breast. In addition, he drills, blasts, and loads the rock encountered in the vein. The miner is also required to stand timber necessary for the support of the friable strata overhead, and to lay rails in his workplace for the movement of cars. The contract miner is paid at a fixed rate per mine car or mine ton of coal produced, or at times by the linear yard. Under abnormal conditions, such as in thin veins

of coal or when an undue amount of rock is to be handled, it is impossible for the miner to earn a fair day's wage by the exertion of reasonable efforts. In such instances he is placed on a "consideration" basis and paid at a daily or hourly rate.

The contract laborer or helper assists the miner in the above-mentioned duties with the exception that he is not allowed by mine law to prepare or fire the explosive charge. He is employed by the miner who may hire and "fire" him at will.

The company miner is paid on a daily or hourly basis and is employed to perform general mine work, such as blasting rock, driving gangways, and setting timber in the main haulageways.

The company laborer is also paid by the company at a daily or hourly wage rate, and assists the company miner in the above duties.

Chute loaders are employed in filling mine cars with coal delivered from a chute in pitch mining operations. The chute loader is stationed at the bottom of the chute and controls the flow of coal into the car by means of a drop gate.

Starters are men engaged in pushing the coal down a chute during the loading process.

Scraper loaders perform duties similar to a chute loader, with the exception that the car is loaded by means of a scraper shovel instead of by gravity.

Scraper loader engineers operate hoisting engines, which are used to haul the empty scraper to the far end of the coal cut, and to pull this scraper forward, bringing the coal to the mine car stationed in the gangway.

Shaker loaders are engaged in loading cars with coal delivered to the car by means of a shaker conveyor.

OPENING WORK

Tunnel and rock workers are engaged in driving gangways, chutes, and airways through rock. This work is sometimes done by the company miners, but is generally awarded on a contract basis to a rock contractor employing men solely engaged in this type of work. The work consists of drilling holes with a Leyner drill, and charging them with explosives.

Muckers load the rock which has been blasted by the *chargemen*, into mine cars, and are employed in keeping the workplaces clean. In some mines, laborers known as *slatemen* are engaged in filling abandoned workplaces with rock.

VENTILATION

Fire bosses are officials who examine the various workplaces in a mine for the presence of dangerous gases, and who have charge over

FIGURE 10.—DRILLING WITH JACKHAMMER.

FIGURE 11.—MINER HAND DRILLING.

the removal of such gases. This work is done at night, and completed before the miners enter the mine in the morning.

Bratticemen, carpenters, and masons are employed to erect partitions in the mines for directing air currents. These partitions may be of cloth, wood, or masonry.

Door tenders and doorboys open and close mine doors during the passage of a train of cars.

TRANSPORTATION

Loader and driver bosses supervise the loading of mine cars, and the transportation of these cars from the various workplaces to the foot of the mine shaft.

Station tenders have charge of the various mine cages.

Shaft, slope, and plane tenders are employed at shaft landings or on planes or slopes where mine cars are being transported. They signal for the raising and lowering of cars, and in the case of the shaft tenders, assist in moving the cars on and off the cage.

Motormen and helpers operate electric locomotives of different types used in the transportation of mine cars.

Patchers, car runners, et al assist the motormen and mule drivers in delivering empty cars, and in removing loaded cars from the various workplaces.

Mule drivers deliver empty cars to the entrance of the miners' workplaces, remove the loaded cars, and deliver them to the foot of the shaft or slope.

Stablemen and helpers have charge of the stables and mules.

Spraggers and car couplers attend to track switches, couple and uncouple cars, and apply "sprags" (short, round pieces of wood pointed at both ends) to the car wheels, to act as brakes in checking the momentum of the cars.

HOISTING WATER

Pumpmen are employed to take care of the underground pumps used to remove the water that accumulates in the workings.

Ditchmen excavate and clear gutters in the floor of the gangways or airways to facilitate the flow of water to a sump.

TIMBERING

Timberers and helpers are employed to place timber to hold the friable layers of coal and strata overlying roadways, gangways, etc.

MAINTENANCE

Trackmen and helpers lay and maintain rails used for the haulage of cars in the mines.

Road cleaners (roadmen) maintain the mine roads in good condition, and keep them generally clean and free from debris.

Shaftmen and helpers maintain the shafts in good condition.

Pipe men and helpers lay and maintain pipes for conveying water and compressed air.

Machinists and electricians install and maintain all mechanical and electrical equipment underground.

SUPERINTENDENCE

Mine foremen and assistant mine foremen are responsible for all underground operations.

Clerks and timekeepers perform clerical duties such as timekeeping and checking the number of cars of coal hauled to the shaft.

Lampmen maintain and have charge of all safety and electrical cap lamps and batteries.

Culm bosses supervise the disposal of mine debris.

OUTSIDE FORCE

TRANSPORTATION

Topmen, footmen, headmen, and helpers are employed on shaft landings or on planes or slopes where mine cars are being transported. The headmen give signals for lowering the cars, and the footmen give the hoisting signals. They also couple and uncouple cars, and, in the case of shaft hoisting, assist in moving the cars on and off the cage.

Shaft, slope, and plane tenders.—See above definition.

Car haul operators, shaft, slope and tower engineers operate the hoisting engines used to raise and lower mine cars in shafts, and on planes and slopes.

Car oilers oil and grease the axles of mine cars.

Locomotive engineers, firemen, and brakemen comprise a crew which drives and fires the steam locomotives used for hauling coal or waste outside.

Sandmen screen and dry sand before its use underground.

Spraggers.—See definition for inside spraggers.

Teamsters, yardmen, and locomotive watchmen are self-explanatory.

MAINTENANCE

Timbermen are employed in cutting and preparing timber for use inside. The remaining 11 occupations listed under "Maintenance" in table 2 appear to be self-explanatory.

LIGHT, HEAT, AND POWER

The occupations listed for this section are also self-explanatory.

PREPARATION

Dumpers are employed to release the tilting door of a mine car as it reaches the top of a breaker tower, thus permitting the coal to slide out of the car into a gathering chute.

Plane tenders are engaged in some breakers which use planes for conveying the mine coal to the breaker tower. They give signals and switch cars and perform general duties about the plane.

Platform men and chippers remove the rock from the run-of-mine coal, and chip off any slate or "bone" adhering to the large lumps of coal.

Screen, elevator, and conveyor tenders work about the screens, elevators, and various belt conveyors used in the cleaning process.

Jig tenders are employed about the jigging tables which are used in the cleaning and separation of coal by water flotation.

Cone attendants are employed about the Chance cones used in the separation of coal by the sand flotation system.

Rock trappers operate mechanical gate valves used to remove rock from the bottom of the Chance cone.

Slate pickers separate manually the slate and "bone" from the coal before it passes to the storage hoppers.

Loaders, car runners, and cleaners are employed in cleaning, operating, switching, and loading freight cars (gondolas) used in the shipment of coal.

The remaining occupations enumerated for this section are explained by their designations.

REFUSE

Rock bank men are engaged in the disposal of waste rock and debris.

Bore hole attendant is engaged in returning silt and other refuse through a bore hole or a pipe in the mine shaft to places in the mine that need filling for support of the mine roof.

Dorr thickener operator attends the hydro separator used in the settling of fine coal in the general cleaning process.

The remaining occupations in this section need no explanation.

SUPERINTENDENCE

Superintendents and assistant superintendents are directly responsible for all underground and surface activities at a colliery.

Courthouse men are employed at certain collieries to inspect coal in mine cars suspected of containing an excessive amoung of rock.

The remaining occupations in this section are self-explanatory.

TYPICAL MINER'S ACTIVITIES

In order to give a more complete picture of the activities of a miner during the course of a day's work, the following tabular descriptions

are presented, which show the time consumed in the performance of the fundamental operations in two different types of mining.

A. Driving gangway in rock and coal

[Three miners]

Time of day	Activity
A. M.	
7:00	Arrived at tool box outside of heading and started to eat breakfast.
7:20	Started to load rock at face. (Rock blown the previous day.)
8:02	First car loaded.
8:22	Loaded car removed and empty car brought in by driver.
8:58	Second car of rock loaded.
9:17	Loaded car removed and empty brought in by driver.
9:42	Third car of rock loaded and miners start to clean road bed.
9:53	Driver removes loaded car, brings in empty car and 30 foot rail.
9:55	Start to load empty car.
10:35	Fourth car of rock loaded, miners start eating.
10:55	Loaded car removed, and empty brought in. Firing in nearby chamber causes delay.
11:05	Lay rail, pulling up 15 foot temporary rail.
12:00	Dress face so as to start drilling in coal.
P. M.	
12:20	Start to drill four holes 5 feet 6 inches in depth in coal.
12:53	Tamp holes with 17 sticks of R. H. Dynamite. Use four delay caps and ⅛ roll of paper.
1:10	Fire. Air being good, smoke cleared without delay.
1:15	Start to load coal.
1:35	First car of coal loaded.
1:45	Three holes drilled in face 5 feet 6 inches in depth, 2 in seam, and 1 in top coal.
2:00	Tamp holes and use 12 sticks of dynamite. String 30 feet of copper wire to battery (3 delay caps used).
2:16	On way to shaft. Pull pegs at 2:45 p. m.

SUMMARY

Spent 48 minutes drilling 10 holes in coal face, 20 minutes in loading one car of coal, and 114 minutes in loading 4 cars of rock. Advanced 8 feet in coal face, which is 3 feet 8 inches on high side and 2 feet 4 inches on low side.

B. Shaker loader operation

[Three miners at breast and a loader in the gangway]

Time of day	Activity
A. M.	
7:00	Arrived at breast.
7:01	Started to eat breakfast.
7:05	Finished eating.
7:15	Started to dress off face.
7:45	Started to drill in coal face with hand drill.
8:02	Finished drilling a 6-foot hole.
8:10	Started to charge holes and fired.
8:17	Dressed off face and started to fill shaker.
8:30	Started second hole.
8:45	Trip of cars arrived; started to load empty car.
8:50	Finished second hole 6 feet deep.
9:00	Finished loading first car.
9:01	Started loading second car.
9:06	One-half of second car loaded; shaker stops owing to some difficulties with current.
9:11	Shaker started again.
9:15	Second car loaded and hauled away.
9:17	Second hole charged and tamped.
9:28	Second hole fired.
9:30	Empty cars arrive; miners start to eat.
9:37	Miners go back to the face.
9:40	Start loading third car with shaker loader.
9:52	Third car loaded.
9:53	Start loading fourth car.
10:06	Fourth car loaded and hauled away.

B. Shaker loader operation—Continued

[Three miners at breast and a loader in the gangway]

Time of day	Activity
A. M.	
10:08	Miners load shaker at the breast.
10:28	Empty cars brought in gangways, but miners are not ready to load.
10:40	Start hole in face with hand drill.
11:02	Hole finished.
11:06	Hole tamped and ready for firing.
11:10	Hole fired.
11:18	Miners start to load car.
11:28	Fifth car loaded.
11:36	Sixth car loaded and hauled away.
11:45	Miners eat.
11:55	Miners go to breast and start drilling hole by hand.
P. M.	
12:23	Hole finished and tamped.
12:33	Hole fired. (Only 1 car brought for loading.)
12:36	Start to load seventh car.
12:47	Seventh car loaded.
1:00	Firing in nearby breast causes delay.
1:15	Start to drill 4-foot hole for heading.
1:35	Hole finished and miners charge hole.
1:45	Hole fired.
1:50	Miners return to face and trim breast.
2:00	Miners leave breast.
2:30	Miners pull pegs at talley board.

SUMMARY

Spent 97 minutes drilling 5 holes by hand drill, and 91 minutes in loading coal. Advanced approximately 5 feet; vein 6 feet 5 inches in height at a 5° pitch. Face about 75 feet from gangway. Shaker end about 10 feet from face and 65 feet in length. Total delay during the day, 12 minutes.

4. RESULTS OF STUDY

VENTILATION

Before the dust surveys were made, each mine was inspected for the purpose of locating representative working places for dust studies. In connection with these preliminary inspections, certain ventilation observations were made, data being obtained on the atmospheric conditions existing at the face or breast of various workplaces.

The coal in the veins of mine no. 1 was very dry, while that in mines no. 2 and 3 was wet. In all three mines the air supply was ample, judged from the standpoint of present mine laws, which require a minimum of 200 cubic feet of air per minute for each man underground.

In practically all mines the air underground is supplied by huge ventilating fans operated either by steam or by electricity. These fans resemble a short water wheel, varying from 10 to 35 feet in diameter. Foul air is drawn from the mine at one point by an exhaust fan revolving at a rapid rate, and pure air is drawn into the mine through intake shafts located elsewhere. After reaching the

mine, the fresh air is carried to many points by a carefully arranged system of airways driven parallel to the gangways or main transportation roads underground, one serving as the route for the fresh air, and the other as the exhaust air return. By means of screens of brattice cloth (a closely woven cloth practically impervious to the passage of air) and wood, the air is carried to the face of each working place. In this way the fumes and gases generated in the blasting operations are replaced with clean air.

Because there are many gangways in a mine, the original incoming air is divided and subdivided many times in the course of its traverse through the workings. These numerous divisions and subdivisions form a very intricate system of channels as one many easily see by studying a typical mine ventilation map (fig. 12).

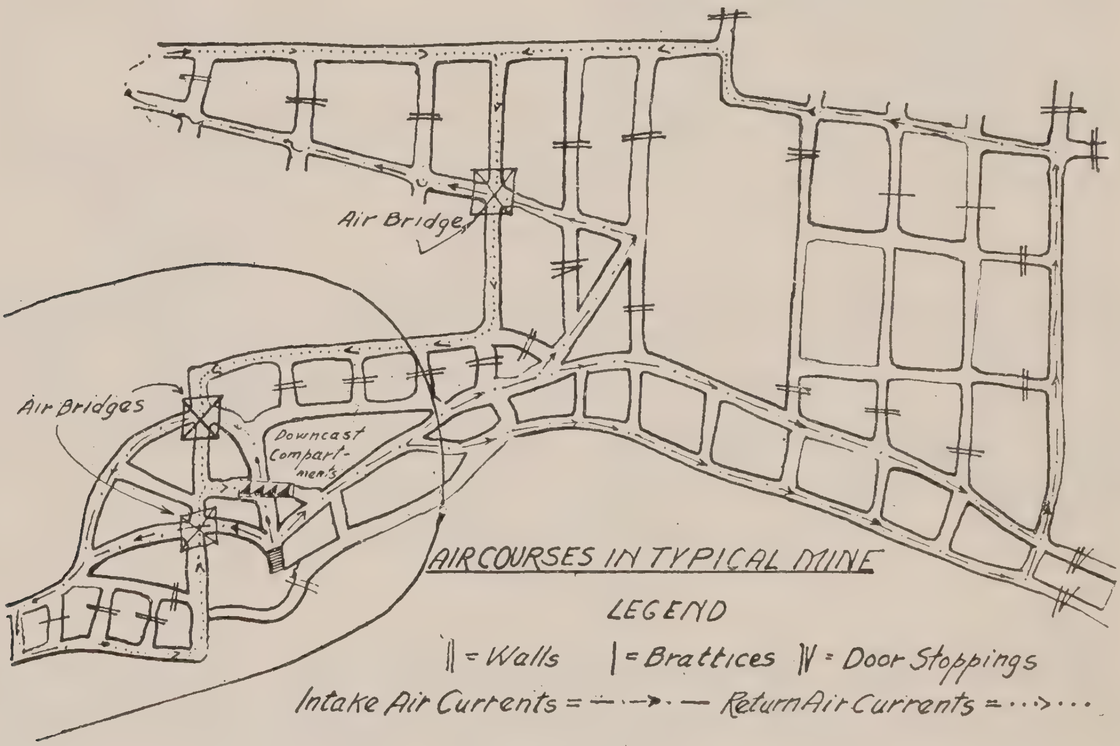


FIGURE 12.

From table 3 which shows the ventilation facilities studied, it is apparent that these mines supply more than the required 200 cubic feet of air per minute per man. However, this is only the amount of air entering the mines; it affords no information concerning the amount of air at any particular workplace, especially in those workplaces at a great distance from the air intake shaft. In fact, it is not a very simple matter to determine the actual volume of air supplied to each workplace. This statement may be easily appreciated when one considers the irregularities of the miners' chambers and the difficulty in distinguishing between useful and turbulent air currents.

TABLE 3.—*Ventilation facilities in the anthracite mines covered by this study*

Type of fan	Size of fan (diameter in feet)	Capacity (cubic feet per minute)	Number of men employed	Number of cubic feet per minute per man	Remarks
Geibels	35	290,000	1,134	489	Mine laws call for 200 cubic feet of air per minute for each underground worker.
Do	35	265,000	1,134	489	
Jeffrey	10	216,000	508	740	
Do	12	160,000	508	740	

In the preliminary inspection of the mines in question, numerous ventilation observations were made in an effort to determine the actual air conditions existing at the workplaces. These observations are summarized in table 4.

TABLE 4.—*Ventilation observations at working face in three anthracite mines*

Observation	Dry bulb temperature (° F.)	Percent relative humidity	Air velocity (feet per minute)	Effective temperature (° F.)
Minimum	50.2	89	10	50
Maximum	68.0	97	330	61
Average	58.5	92	[1] 42	59

[1]Median.

An examination of table 4 shows that air temperatures ranged from 50 to 68 degrees Fahrenheit, averaging 58.5° F. Relative humidities were rather high, but fairly constant, ranging from 89 to 97 percent, and averaging 92 percent. It may readily be seen that dry and wet-bulb temperatures were fairly uniform throughout the mines. However, a wide range of air velocities was disclosed in studying the air movement at typical workplaces. These velocity studies indicated many readings in the order of 10 feet per minute[3] and several as high as 300 feet per minute. This variation depends on numerous factors, such as the distance of a face from the main airways, and the necessity of conducting mining operations in "dead ends" until passageways have been created joining one chamber with another, thus facilitating proper ventilation. Slightly more than 50 percent of the air-velocity observations were found to be less than 50 feet per minute. At the present time there are no standards for the degree of air movement necessary in mine workplaces for the removal of noxious gases and dusts, nor are we in a position to advocate any from our limited data. However, we found that the effective temperatures[4]

[3] In certain breasts the ventilation was not of the best, it being necessary to augment air supplied by the main fans with air from a 1-inch compressed air line. In one instance velocity readings showed that the air movement at the breast was increased from an average of 59 to an average of 113 feet per minute by the use of compressed air.

[4] Effective temperature may be defined as that temperature of saturated air which, moving at a velocity of 15 to 25 feet per minute would produce the same sensation of warmth or cold as that produced by the combination of temperature, humidity, and air motion under observation.

existing at the various work places as shown in the above table, were within the comfort range of men performing hard work (7).

DUST STUDIES

It has already been indicated that in evaluating the potential hazard of dust inhalation, the principal factors to be considered are the nature and concentration of the dust in question. The duration of exposure is obviously important, and may be determined from a careful occupational history of each worker. It is now fairly well established that nearly all atmospheric industrial dust is of a size capable of gaining ready access to the lung tissue. However, the size of the dust suspended in the working environment may be of some interest, since this additional information may cast light on the pathological significance of various sizes of dust particles. The remainder of the report on working environment, therefore, presents the results of a study of the nature, size, and concentration of the dust associated with the various occupations involved in the mining and preparation of anthracite coal.

NATURE OF DUST

Nineteen samples of dust settled out at the breathing level in different working places were obtained for the purpose of determining the composition of the dust to which anthracite workers are exposed. These samples were subjected to chemical and mineralogical analysis. Table 5 presents a summary of the sources of the samples obtained for these analyses.

TABLE 5.—*Sources of samples of dust obtained from three anthracite mines for chemical and mineralogical analysis*

Number of samples	Source of samples; dust settled out—	Occupations exposed
5	In main haulageways and in return air-tunnels.	Men included in the following sections: Ventilation, transportation, maintenance, hoisting water, timbering, and superintendence.
3	At face of gangways where rock drilling was in progress.	Rock workers and coal miners working in top and bottom rock.
3	At coal face in chamber mining	Chamber miners and laborers.
3	At breast in pitch mining	Pitch miners.
4	In breaker	All breaker workers.
1	Fine coal taken from 46 representative coal cars (gondolas).	

The chemical analyses were conducted in the laboratories of the United States Public Health Service by Associate Chemist F. H. Goldman; for the petrographic analyses we are indebted to the United States Bureau of Mines, and especially to Dr. E. P. Partridge of that Bureau. Several samples were obtained for the four broad occupational groups listed in table 6. The percentages shown in the table represent averages of the samples for each group.

The first section of table 6 presents the average chemical composition of the samples. It will be seen from these data that for miners and their laborers, as well as for all breaker workers, the loss on ignition, which in coal samples may be assumed as representing the volatile matter present in coal, is quite high, being about 75 percent. In contrast, the percentage of 6 obtained for rock workers indicates that these persons are exposed to dust of high inorganic content. The men employed in general underground activities show an intermediate exposure, which may be attributed to the fact that the haulageways are sanded and the air contains dust arising from both coal and rock operations. The total silica found in these samples clearly indicates that coal miners and breaker workers are exposed to lower percentages of total silica (about 12 percent) than are the rock workers (63 percent), while the other inside employees work in dust containing about half as much silica as was found in the dust to which rock workers are exposed.

In determining the amount of rock impurities in the samples, we computed the figures presented in section 1 on the basis of an analysis obtained from a sample of coal which had been thoroughly freed from impurities. The recomputed results are given in section 2 of table 6. The first column of this section shows the percentage of dust in the form of coal to which the various occupational groups are exposed. These figures were obtained by dividing the loss on ignition shown in the corresponding column of section 1, by the loss on ignition found for the pure coal sample. For example, inasmuch as the pure coal sample showed a loss on ignition equal to 87.6 percent, and the loss on ignition for the miners' samples was found to be 78.7 percent, the actual coal content of the latter samples must be 78.7/87.6 or 89.5 percent. Obviously, the percentage of coal when subtracted from 100 percent should yield the percentage of inorganic matter present in the samples. These differences (percentage inorganic matter) are given in the second column of section 2.

The quantity of total silica in the pure coal sample was found to be 6.4 percent. This value multiplied by the results for the percentage of coal given in the first column of section 2 should give the percentage of silica combined with the coal. The results obtained in this manner are shown in the third column of section 2. The percentage of silica combined with rock shown in the fourth column of section 2 follows naturally as a difference between the results given in the second column of section 1 and the third column of section 2. The petrographic analyses of rock samples showed an average quartz content of 43.3 percent. Consequently, the results given in the fourth column of section 2 when multiplied by 43.3 percent should yield the percentage of silica as quartz. The results for the percentage of quartz obtained in this manner are given in the last column of sec-

TABLE 6.—*Chemical and petrographic analyses of 18 samples of dust from anthracite coal mines*

Occupational exposure	Section 1. Average chemical composition of samples (percentage)						Section 2. Constituents found by computation from results of chemical analyses (percentage)					Section 3. Constituents found from petrographic analyses	
	Loss on ignition	Total SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Coal	Inorganic matter	SiO_2 combined with coal	SiO_2 combined with rock	SiO_2 as quartz	Percentage quartz	Other minerals
All miners and laborers (6 samples)	78.7	11.1	1.6	6.7	1.6	0.4	89.5	10.5	5.7	5.4	2.3	3.9	Calcite, muscovite, epidote, sericite, and siderite.
Rock workers (3 samples)	5.9	63.2	4.8	23.5	.6	.8	6.7	93.3	.4	62.8	27.0	43.3	Muscovite, siderite, sericite, rutile, epidote, limonite, and biotite.
All other inside workers (5 samples)	50.5	33.7	4.6	9.3	1.1	.7	57.6	42.4	3.7	30.0	12.9	13.0	Calcite, muscovite, sericite, biotite, rutile, and kaolinite.
All breaker workers (4 samples)	73.6	13.5	4.8	6.3	.8	.6	84.2	15.8	5.4	8.0	3.4	5.3	Calcite, sericite, rutile, siderite, and limonite.

tion 2. These computed values agree quite closely with the actual percentages of quartz as determined by petrographic analyses of the samples, as may be seen by comparing the computed results with the petrographic analysis shown in section 3.

It may be seen from the results shown in sections 2 and 3 that miners are exposed to a dust consisting of about 90 percent coal, and between 2 and 4 percent quartz. Rock workers, however, are exposed to dusts consisting mainly of inorganic matter of which 27 to 43 percent is quartz. Again it will be seen that all other underground workers are exposed to dusts containing values for quartz and coal intermediate to the other two groups of workers. The other mineral constituents of the dusts collected in these mines are shown in section 3.

The results presented in table 6 again indicate the value of a combined chemical and petrographic (mineralogical) analysis in investigations of dust from an industrial hygiene standpoint. It may also be of interest to point out that the results given in table 6 compare very closely with those obtained in a similar investigation of the dust problem in anthracite coal mines conducted by this office several years ago (*8*).

SIZE OF DUST

The dust samples used for particle-size determinations were obtained with the Owens instrument, and represent the dust actually suspended in the atmosphere at the breathing level of the worker. The results of the measurements of 1,500 particles are summarized in table 7.

TABLE 7.—*Summary of size-frequency distribution of dust suspended in the air of three anthracite mines*

Nature of process and kind of dust	Number of particles measured	Median size (in microns)	Percentage frequency of each particle-size group (in microns)								
			0–0.49	.50–0.99	1.00–1.49	1.50–1.99	2.00–2.49	2.50–2.99	3.00–3.49	3.50–3.99	Total
General air in breaker	300	1.00	7.0	51.0	26.0	8.0	3.0	3.0	2.0	0	100.0
Coal drilling	200	.96	1.0	55.0	34.5	7.5	1.5	0	.5	0	100.0
Coal loading (hand)	200	.82	9.0	62.0	22.5	5.0	1.0	0	.5	0	100.0
Coal loading (chute)	200	.78	14.5	56.5	24.0	4.5	0	0	0	0	100.0
Coal loading (shaker)	200	.88	11.0	50.5	26.5	7.0	3.5	1.5	0	0	100.0
General mine air	200	.88	11.0	60.0	17.0	7.0	3.0	1.0	1.0	0	100.0
Rock drilling	200	1.02	4.0	49.0	25.5	12.5	5.5	1.5	.5	1.5	100.0
Total	1,500										
Average		.91	8.2	55.6	25.0	7.5	2.0	1.0	.5	.2	100.0

From table 7 and figure 13, in which the percentage of particles is shown by size-groups, it may be seen that all the dust suspended in the different workplaces in the mines was less than 4 microns in longest dimension. Only 8 percent of the dust particles were less

than 0.5 micron, the majority (80 percent) being between 0.5 and 1.5 microns. The median [5] particle-size was 0.91 micron. It is apparent, therefore, that the dust particles are of a size capable of gaining access to the lungs. Figures 14 and 15 are photomicrographs of coal and rock dust suspended in the air of the mines, and illustrate photographically the relative size of the dust particles encountered in this study.

DUST CONCENTRATION

For determination of the amount of dust to which the mine workers were exposed, 300 atmospheric dust samples were obtained with the impinger apparatus. These samples were allotted on the basis of the

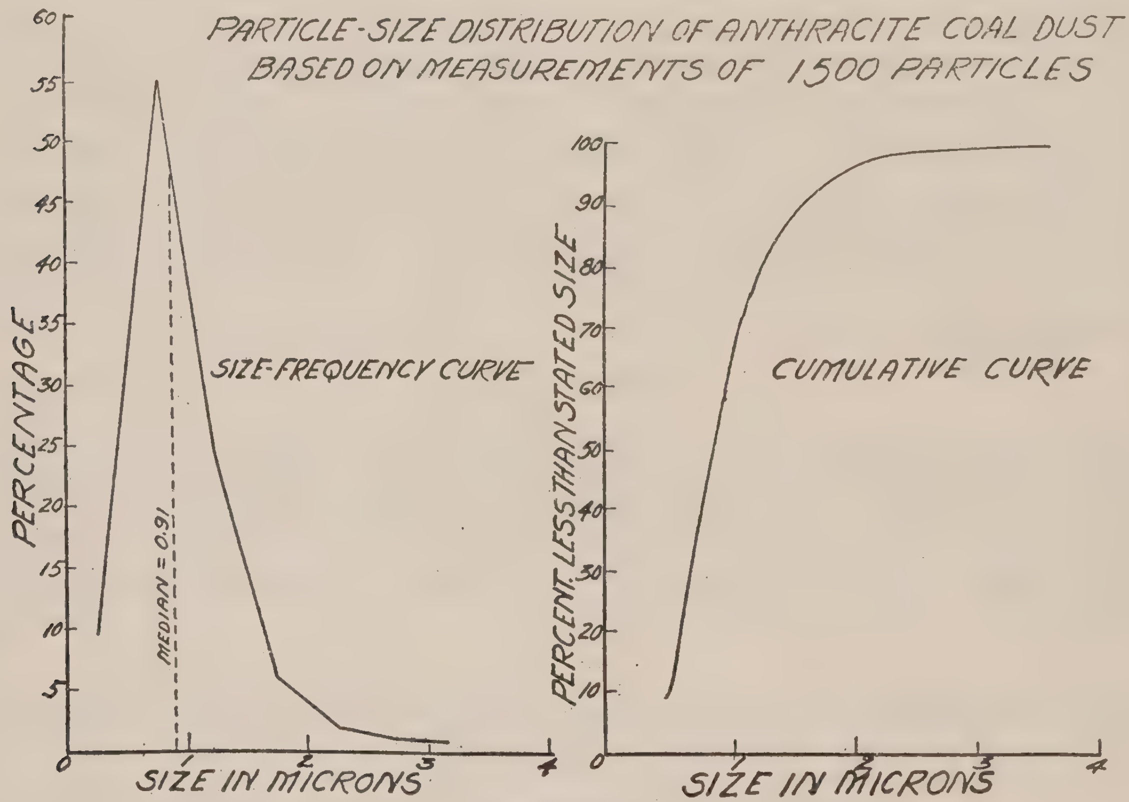


FIGURE 13.

number of workers in each occupation and the importance of the occupation from the standpoint of the amount of dust exposure. In studying the exposure of coal miners and laborers, 114 dust samples were procured. A large number of samples for these two occupations seemed necessary for the following reasons: (*a*) Coal miners and laborers comprised 43 percent of all the workers at the collieries; (*b*) they are exposed to the greatest amount of dust as will be shown later; and (*c*) the four distinct methods employed in mining coal necessitated a large number of samples for the purpose of determining the exposure in each type of mining.

[5] The median is the middle item in an array, and may be strictly defined as a point on the abscissal scale of a frequency distribution with 50 percent of the items on either side.

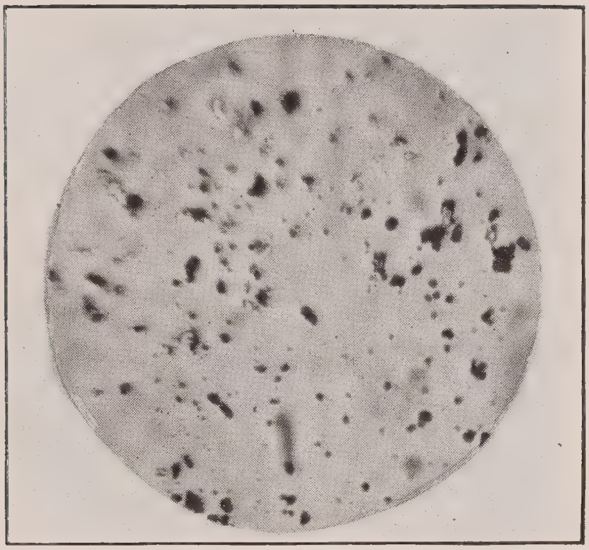


Figure 14.—Photomicrograph of a Mixture of Coal and Rock Dust Suspended in the Air of a Mine (X1,000).

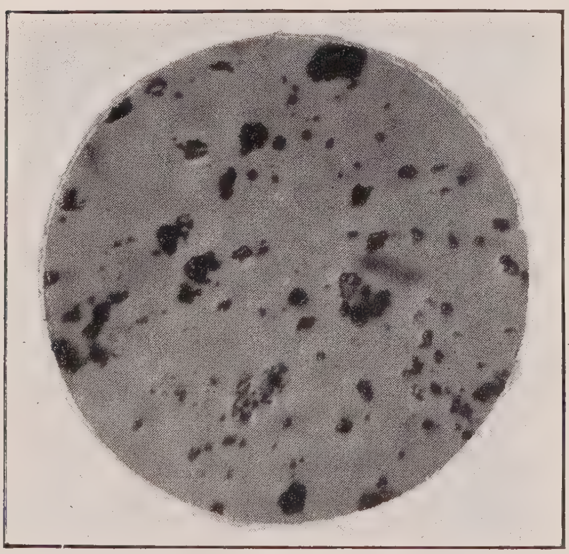


Figure 15.—Photomicrograph of Coal Dust Suspended in the Air of a Mine (X1,000).

CHAMBER MINING

In table 8 the dust exposure of contract miners employed in chamber or room mining is shown. Each activity engaged in by these coal miners was studied separately because the different operations involved in a dusty occupation are often associated with dissimilar dust exposure.

TABLE 8.—*Dust exposure of contract miners and their helpers (laborers) engaged in chamber mining*

Activity	Number of samples taken	Number of hours in activity	Average dust count (millions of particles per cubic foot)	Millions of particle-hours per cubic foot
Jack-hammer drilling	23	1	575	575
Hand loading	22	2	1, 138	2, 276
After firing	7	¼	834	209
Tamping and wiring	2	½	40	20
Setting up props, and in main airways	8	2¾	15	41
Total	62	6½		3, 121

$$\frac{3{,}121 \text{ million particle-hours per cu. ft.}}{6\frac{1}{2} \text{ hours}} = 480 \text{ million particles per cu. ft.}$$

It is apparent from table 8 that the hand loading of coal contributes about 75 percent of the total dust exposure of chamber miners and laborers, although this activity comprises less than one-third of the total working hours. Jack-hammer drilling which consumes only 1 of the 6½ hours in the miner's workday accounts for 18 percent of the total exposure, while the practice of entering a room too soon after blasting unduly exposes miners to a large amount of dust (about 7 percent of the total dust exposure). It is evident from this differential analysis of a miner's dust exposure that drilling and loading coal which involve slightly less than one-half of the miner's time in any one day are responsible for 91 percent of the total dust exposure. In attempting to minimize the dust hazard it is obvious that effort should be concentrated on the reduction of dust in the two activities involving the greatest exposure.

That chamber miners and laborers breathe great quantities of dust is evident from the weighted average obtained, namely, 480 million particles per cubic foot of air. It is of interest to point out that the average dust count obtained from the 62 samples for chamber miners without regard to the duration of exposure to the dust associated with each activity was 714 (as contrasted with 480) million particles per cubic foot of air.

PITCH MINING

In pitch mining it was observed that practically all the holes made in the coal breast were drilled by hand with the aid of the churn and pick drills. Pitch miners did not load the coal; when a charge was

fired and the breast picked and trimmed, the coal was dropped down an iron chute into an empty car beneath the chute in the main gangway. In view of the difference in the activities of pitch miners as compared with chamber miners, a difference in the dust exposure is to be expected. This expectation is confirmed by the data shown in table 9.

TABLE 9.—*Dust exposure of contract miners engaged in pitch mining*

Activity	Number of samples taken	Number of hours in activity	Average dust count (millions of particles per cubic foot)	Millions of particle-hours per cubic foot
Hand drilling	8	2	175	350
Trimming and dressing	4	1	862	862
Tamping and wiring	2	½	1. 6	. 8
Setting props, laying coal chutes, and in main airways	17	2½	3. 2	8
Total	31	6		1, 220. 8

$$\frac{1{,}220.8 \text{ million particle-hours per cubic foot}}{6 \text{ hours}} = 203 \text{ million particles per cu. ft.}$$

The dust produced in pitch mining averaged 203 million particles per cubic foot of air as contrasted with 480 million particles in chamber mining. Although the activity of trimming and dressing the coal breast with a pick lasts only 1 hour per day, it contributes about 70 percent of the total dust exposure of pitch miners. Hand drilling is the next dustiest operation; it accounts for about 29 percent of the dust exposure. Accordingly, drilling and trimming and dressing the breast, which take up about one-half of the miner's working day, cause 99 percent of the dust.

SCRAPER LOADER MINING

The dust exposure of contract miners using the scraper loader or drag shovel for removing coal from the breast and loading it into mine cars is shown in table 10.

TABLE 10.—*Dust exposure of contract miners using scraper loader*

Activity	Number of samples taken	Number of hours in activity	Average dust count (millions of particles per cubic foot)	Millions of particle-hours per cubic foot
Jack-hammer drilling	23	1	575	575
Trimming and dressing	4	1	20	20
Scraper loading	6	2	4. 4	8. 8
Tamping, wiring, setting props, etc	17	3	3. 2	9. 6
Total	50	7		613. 4

$$\frac{613.4 \text{ million particle-hours per cu. ft.}}{7 \text{ hours}} = 88 \text{ million particles per cu. ft.}$$

When the top and bottom rock is not removed in a workplace, the coal must be transported from the face or breast to the haulageway before it is loaded into mine cars. Under such conditions mechanical loading methods are frequently employed, such as the use of a scraper loader or a shaker loader. Observation of miners using a scraper loading device showed that their greatest exposure came from the use of the jack-hammer in drilling holes. This activity accounted for 94 percent of the miner's total dust exposure, although the miner used the drill for only 1 hour a day. The remaining activities in this type of mining were found to be associated with relatively low dust counts, as shown in table 10. The coal in the mine where scraper loading was employed was naturally wet, so that even the operation of trimming and dressing the breast was accompanied by a low dust exposure.

SHAKER LOADER MINING

Table 11 presents the dust determinations made for the purpose of ascertaining the exposure of miners using the shaker device for removing the coal from the breast. The average amount of dust to which these miners were exposed was 56 million particles per cubic foot of air. Approximately 73 percent of the total dust exposure recorded for the entire 7-hour day was caused by 30 minutes of jack-hammer drilling.

TABLE 11.—*Dust exposure of contract miners using shaker loader*

Activity	Number of samples taken	Number of hours in activity	Average dust count (millions of particles per cubic foot)	Millions of particle-hours per cubic foot of air
Hand drilling	4	1½	12	18
Jack-hammer drilling	23	½	575	287.5
Trimming and dressing	4	1	20	20
Loading shaker	7	1½	39	57.5
Tamping, wiring, setting props, etc	17	2½	3.2	8
Total	55	7		391

$$\frac{391 \text{ million particle-hours per cu. ft.}}{7 \text{ hours}} = 56 \text{ million particles per cu. ft.}$$

COAL LOADERS' EXPOSURE

The dust exposure of various workers engaged in loading coal into mine cars is shown in table 12.

In room mining, the miner and his helper load the coal manually, as previously described. In pitch mining, and in those mines where mechanical means are used for loading coal, special workers are assigned to control the flow of coal into the cars, and, in general, to supervise the filling and movement of these cars at the loading point. From table 12 one may note that chute loaders are exposed to an average dust concentration of 291 million particles per cubic foot.

TABLE 12.—*Dust exposure of various workers engaged in loading coal*

Occupation and activity	Number of samples taken	Number of hours in activity	Average dust count (millions of particles per cubic foot)	Millions of particle-hours per cubic foot of air
Chute loaders and starters:				
Loading	12	5	464	2, 320. 0
In main airways	17	3	3. 2	9. 6
Total	29	8		2, 329. 6
Weighted average: 291 million particles per cubic foot.				
Shaker loaders:				
Loading	4	2	95. 0	190. 0
In main airways	17	6	3. 2	19. 2
Total	21	8		209. 2
Weighted average: 26 million particles per cubic foot.				
Scraper loaders:				
Loading	4	3	4. 8	14. 4
In main airways	17	5	3. 2	16. 0
Total	21	8		30. 4
Weighted average: 3.8 million particles per cubic foot.				
Scraper loader engineers	17	8	3. 2	

The loader receives a high dust exposure for the 5 hours a day during which he controls the flow of coal from the chute into the car. At the start of the loading process the coal drops a distance of about 4 feet, and, being rather friable and dry, it raises large clouds of dust. In the shaker and scraper loading processes, the movement of coal was not as rapid as in the gravity chute operation; hence less dust was generated. The dust exposure for shaker and scraper loaders, and for the engineers operating the hoisting engines in connection with the scrapers was found to be relatively low, namely, 26, 3.8, and 3.2 million particles per cubic foot of air, respectively.

ROCK WORKERS

As was shown earlier in this report, a certain amount of rock excavation is necessary in every mine. Certain gangways, airways, chutes, and slopes are driven entirely in solid rock. This work is usually done by special crews hired by a contractor. As a rule these men devote their entire life to rock work. Since rock work is not an everyday necessity in a mine, it is customary for these men to carry on their trade from mine to mine. During the present study 130 such workers were found in opening work. The dust counts made to determine the exposure involved in this type of work are presented in table 13.

TABLE 13.—*Dust exposure of rock workers in anthracite coal mines (dry process only)*

Occupation and activity	Number of samples taken	Number of hours in activity	Average dust count (millions of particles per cubic foot)	Millions of particle-hours per cubic foot of air
Rock drillers:				
Drilling	17	2½	568	1,420
Other duties	25	3½	7	24
Total	42	6		1,444

Weighted average: 241 million particles per cubic foot.

Occupation and activity	Number of samples taken	Number of hours in activity	Average dust count (millions of particles per cubic foot)	Millions of particle-hours per cubic foot of air
Rock loaders (muckers and slatemen):				
Loading	2	5	636	3,180
Other duties	25	1	7	7
Total	27	6		3,187

Weighted average: 531 million particles per cubic foot.

In several respects the work of a rock driller is similar to that of a coal miner, especially as regards the drilling and firing operations. Rock drillers use a Leyner machine for making holes in the face of their workplace, which until recently was done in most hard-coal mines without the use of water to allay the dust generated. For this reason the dust counts found in the dry process only are presented. It is apparent that rock drillers, as well as those men employed in loading the rock into mine cars, are exposed to exceedingly high-dust concentrations, the average being 241 million for rock drillers, and 531 million particles per cubic foot for loaders.

TRANSPORTATION WORKERS (UNDERGROUND)

Observation of the working environment of the men engaged in transporting coal from the various workplaces to the surface indicated that the data on underground transportation workers should be presented separately for each mine. Dissimilar practices and conditions were found especially for the shaft, slope, and plane tenders, and for motormen, mule drivers, and runners, as may be inferred from an examination of table 14.

TABLE 14.—*Dust exposure of inside transportation workers*

Occupation	Number of samples taken	Average dust count (millions of particles per cubic foot)
Loader and driver bosses, stablemen, and helpers	25	6.9
Shaft, slope, and plane tenders:		
Mine no. 1	7	24.8
Mines nos. 2 and 3	19	3.1
Spraggers and car couplers	25	6.9
Motormen, et al.:[1]		
Mine no. 1	8	71.3
Mine no. 2	20	[2]233.3
Mine no. 3	13	3.1

[1] See detailed occupational analysis for other occupations.
[2] Weighted average. High dust count due to exposure during loading.

The dustiest work occurs in the handling of trips of full and empty cars, performed by the motormen and by the mule-team drivers. In mine no. 1, the dry mine in this study, the average dust exposure of motormen et al. was 71 million particles per cubic foot. The greatest dust concentration occurs during the transportation of empty cars, because the coal dust remaining in the "empties" is shaken during the haul over the uneven road beds in the mine. In mine no. 2 the high count of 233 million particles per cubic foot for motormen is due to the method of loading coal practiced in this mine. The coal is loaded from chutes, 3 to 4 cars usually being loaded during a half-hour period. The motorman delivers the cars as needed beneath a chute, pushing them with his locomotive a few feet at a time as directed by the loader. This practice necessitates the presence of the motorman close to the loading chute throughout the period when dust is being generated in large quantities.

In mine no. 3 the use of shaker and scraper loaders, and the fact that the coal is naturally very wet, resulted in the low dust exposure of 3 million particles per cubic foot for motormen.

OTHER INSIDE WORKERS

Table 15 appears to require little explanation other than the statement that the small amount of dust encountered by men in the superintendence section is due largely to the division of their time between inside and surface activities. Since the outdoor air was found to contain less dust than the mine air, it is obvious that the average exposure of the men in superintendence is less than that of the other mine workers under consideration.

TABLE 15.—*Dust exposure of certain inside and certain outside workers*

Section [1]	Number of samples taken	Average dust count (millions of particles per cubic foot)
Inside workers:		
Ventilation, timbering, maintenance, and hoisting water	25	6.9
Superintendence	59	2.9
Outside workers: General maintenance, surface transportation; light, heat, and power; refuse disposal, and superintendence	34	2.9

[1] See detailed occupational analysis for occupations in these sections.

OUTSIDE WORKERS

In addition to the group employed in the preparation of coal in the breaker, a number are engaged in miscellaneous activities above ground, such as in surface transportation, general maintenance work, production of light, heat, and power, refuse disposal, and superintendence. As shown in table 15, these men work in air containing less than 3 million particles per cubic foot.

BREAKER WORKERS

The present investigation afforded a comparison of the dust concentrations in wet and dry process coal cleaning, since two of the breakers were of the wet type. In such breakers the coal is handled dry from the time it is dumped until it is crushed, but from this point on it is submerged in water. In the dry breaker the coal is handled without the use of water throughout the entire processes of crushing, separating, and cleaning the coal.

TABLE 16.—*Dust exposure of workers in a wet and in a dry breaker (preparation)*

Occupation	Number of samples taken	Average dust count (millions of particles per cubic foot)		Number of samples taken
		Wet (2 breakers)	Dry (1 breaker)	
Dumpers and plane tenders	7	13.5	71.1	2
Platform men and chippers	7	23.6	68.6	2
Jig tenders or cone attendants	6	11.1	(1)	(1)
Slate pickers	5	6.9	380.0	21
Loaders, car runners, and cleaners	4	2.3	22.1	2
All other breaker workers	2	2.0	330.5	25

1 No such process in a dry breaker.

The results presented in table 16 are very striking; there is no doubt that the wet processing of coal produces less dust than the dry method. The lower dust counts in the wet than in the dry process even in dumping coal and in separating the large pieces of slate from coal on the platforms prior to crushing are due largely to the fact that the coal was wet in nature, and that in one of the wet breakers exhaust ventilation was utilized in conjunction with a rotary method of dumping. The high dust counts in the dry breaker, ranging from an average of 68.6 for platform men to 380 million particles per cubic foot for slate pickers are about as great as in some of the dustier occupations underground, such as mining and loading. In contrast with these exposures, in the wet breakers 22 of the 31 samples (71 percent) showed dust concentrations that were less than 20 million particles per cubic foot.

5. THE INTERPRETATION OF OCCUPATIONAL DUST COUNTS

As previously mentioned, in the consideration of an industrial dust problem when the same kind of dust is involved, the two most important factors are the dust concentration to which the worker is exposed, and the number of years of exposure.

The amount of exposure associated with each occupation in the industry has been presented in some detail. For the purpose of showing the total dust exposure of each worker during his entire mining history, the exposure was expressed in terms of millions of

particle-years per cubic foot of air, weight being given in this way to the number of years of exposure as well as to the dust concentration associated with each occupation.

A question considered was whether the present dust counts are representative of conditions existing in the earlier years of a miner's occupational life. Observations on this point led to the conclusion that the present dust determinations are fairly representative of conditions which have existed in the anthracite-mining industry for the past 30 years at least. The jack-hammer was first used in hard-coal mines in 1909, and has been employed very extensively since 1915. With the exception of the very recent improvements in mechanical loading and the use of wet methods in cleaning coal, conditions may be said to be about the same today as they were 20 or 30 years ago. One of the mines studied still has an old-fashioned dry breaker and handles coal, both inside and outside the mine, in a manner similar to that practiced many years ago. For these reasons it is felt that about the same degree of dustiness has prevailed in these mines for many years. Furthermore, a comparison of present dust counts with those obtained by us in a similar investigation made in this industry in 1926 (*8*) shows practically the same average dust concentrations.

A typical example of the method used in computing a worker's average dust exposure may clarify the technic employed. Such an example is given in the following table:

TABLE 17.—*Method of computing the average dust exposure of each employee*

Occupation	Number of years in occupation	Dust concentration (in millions of particles per cubic foot)	Millions of particle-years per cubic foot of air
Slate picker (dry breaker)	2	380	760
Patcher (dry mine)	2	71	142
Mule driver (dry mine)	3	71	213
Miner's laborer (chamber mining)	3	480	1,440
Miner (chamber mining)	15	480	7,200
Section foreman	5	7	35
Total	30		9,790

$$\frac{9{,}790 \text{ millions of particle-years per cubic foot}}{30 \text{ years}} = 326 \text{ millions of particles per cubic foot}$$

The occupations are arranged in the above table in the order of employment, the last one being the worker's present occupation. It is obvious that consideration of present occupation only would afford very erroneous information concerning this worker's exposure to dust. In the above technic, weight is given to the number of years spent in each occupation as well as to the amount of dust associated with each job. It is felt that in an analysis of this sort one may obtain a fair estimate of a worker's dust exposure and his proper classification. That there is justification for the use of such a method is evidenced

by the fact that a close relationship was found between the number of million particle-years of exposure and the degree of lung impairment found upon physical examination, as will be shown later.

6. METHODS OF MINIMIZING THE DUST HAZARD

The analysis of dust counts according to occupation and, more specifically, the break-down of occupation according to activity and the time spent in each, suggest the lines along which attempts to minimize the dust hazard could be most effectively directed. These suggestions will be presented in the same order as was followed in the discussion of dust counts according to occupation in section 4.

CHAMBER MINING

It has been shown that miners and laborers engaged in cutting and loading coal in chamber or room operations are exposed to an average dust count of 480 million particles per cubic foot. A differential analysis showing the amount of dust associated with each activity disclosed the fact that 98 percent of the total dust exposure of these workers occurs during the three activities of drilling, loading, and reentering the room after firing, activities which consumed about one-half of the time that these men spent underground. Hence, measures taken to reduce materially the dust exposure associated with these three activities would practically solve the dust problem in this type of mining.

As regards the activity of loading coal by hand, an operation which caused 73 percent of the total dust exposure of chamber miners, one way of controlling this dust is to substitute mechanical loading methods for the present hand-loading operations generally employed in chamber mining. As shown in tables 10 and 11, loading coal by means of a scraper exposes the worker to only 4.4 million dust particles per cubic foot of air; the use of shaker loading devices produces a dust count of 39 million particles per cubic foot, whereas the activity of loading coal by hand is associated with the enormously high dust concentration of 1,138 million particles per cubic foot (Cf. table 8).

In places where it is not possible to use mechanical loading methods, thorough wetting of the coal before loading would materially decrease the amount of dust generated in this activity. That there is a real basis for such an assumption is indicated by the results obtained in the present study in connection with the handling of rock. In the loading of rock by hand, an operation very similar to coal loading, the dust exposure of the workers loading dry rock was 636 million particles per cubic foot as contrasted with 32 million particles per cubic foot when the rock was thoroughly wetted prior to loading. From these

139428—36——4

excellent results in rock loading, it appears that a similar practice in coal loading would reduce the dust exposure to a great extent.

Jack-hammer drilling was found to account for about 18 percent of a chamber miner's total dust exposure. In attempting to eliminate the excessive quantities of dust created by this operation (575 million particles per cubic foot as shown in table 8), two possibilities suggest themselves. In metal mines, rock quarries, and, as shown for rock workers in the present study, the use of wet drilling methods materially reduces the dust exposure. For example, wet drilling (feeding water through a Leyner drill) generated only 33 million dust particles per cubic foot of air as contrasted with an average dust count of 568 million particles per cubic foot in drilling rock without the use of water. The application of wet drilling methods in hard-coal mining should result in much lower dust concentrations for this activity.

Where wet drilling methods are not feasible, it might be possible to make use of a dust trap (*9*) for removing dust at its point of origin. This device is being used to remove the dust generated by rock-drilling operations in excavation work, and probably could be employed successfully in hard-coal mines for both coal and rock drilling.

About 7 percent of the total dust exposure of chamber miners and their helpers was due to the resumption of work too soon after firing an explosive charge. The rapidity with which dusty air clears after blasting depends considerably on the amount of ventilation supplied to each workplace. In one poorly ventilated chamber, the dust count 7 minutes after blasting was still 532 million particles per cubic foot. In well-ventilated workplaces, however, the air cleared in a few minutes after firing. The enforcement of a regulation prohibiting workers from reentering a workplace after the firing of a charge until most of the dust has cleared would eliminate this unnecessary exposure. In places that are not well ventilated, it appears from our observations that about 30 minutes should elapse before a miner and his helper are allowed to reenter a workplace after an explosive charge has been set off.

PITCH MINING

The use of water for minimizing the dust hazard in pitch mining is rather limited, because the coal is very friable in the regions where this type of mining is conducted, and also because fresh coal surfaces are constantly being exposed by the operation of trimming and dressing. However, more adequate ventilation facilities for the pitching breasts than those found in the study would decrease materially the dust concentrations in these workings, many of which at present are in dead ends. As previously stated, the observations on air velocity in different workplaces showed that the ventilation in pitching breasts was at times so inadequate that it had to be augmented by compressed air. More adequate ventilation would measurably lessen the dust

exposure of pitch miners. Wherever it is possible to use water for wetting down the coal, it should be used, of course. This would decrease the dust exposure of chute loaders also.

SCRAPER-LOADER AND SHAKER-LOADER MINING

Inasmuch as 94 percent of the total dust exposure of miners using the scraper loader was found to be due to drilling with the jackhammer, it is obvious that a most important measure of control is to substitute wet drilling for dry drilling, or to use a dust-removal device if dry drilling is continued.

Similarly, in shaker-loader mining, the use of wet-drilling methods or dry drilling with a dust-removal device appears to be the best weapon of defense against dust. If, in addition, the coal is thoroughly wetted with water before it is placed on the shaker belt, the dust problem probably would be solved for this group of workers.

COAL LOADERS

Coal loaders get their heaviest dust exposure, of course, during the loading process. This exposure would be greatly lessened by thorough wetting of the coal before it is loaded.

ROCK WORKERS

Studies by other investigators of workers exposed to dust similar in character to that found in this study of rock workers (*10*), and our own studies in the granite-cutting industry (*11*), indicate that continuous exposure to more than 5 to 10 million particles of such dust per cubic foot of air, in time will cause silicosis which frequently terminates in pulmonary tuberculosis. The most promising solution of the problem at the present time appears to be the use of a dust-removal device of the type mentioned in connection with coal drilling, or the use of water, both during the drilling process and before and after loading.

In one of the mines studied all drilling in flat veins was done with Leyner drills using water. The rock brought down by blasting was thoroughly wetted prior to loading, and also after loading into mine cars. That the use of water both in drilling and loading materially decreased the amount of dust in the air is evidenced by the contrasts presented in table 18.

TABLE 18.—*Dust counts under wet and dry methods in the extraction of rock*

Process	Number of samples	Average dust count in millions of particles per cubic foot	
		Dry method	Wet method
Drilling	23	568	33
Loading or mucking	10	636	32

It is apparent that the use of water reduced the dust count from about 600 to 32 million particles per cubic foot. Obviously, this is a very large reduction in air dustiness, but even lower dust counts may be obtained by the use of dust-removal devices of the exhaust type. As has been indicated, an exposure of 30 million dust particles per cubic foot of air is hazardous when the quartz content of the dust is as much as 35 percent. For this reason all rock workers in hard-coal mines should wear efficient respirators until the dust concentration is reduced to the safe limit mentioned above.[6]

TRANSPORTATION WORKERS (UNDERGROUND)

The suggestion made previously in connection with loaders, namely, the wetting of coal at the face or breast prior to loading, applies also to transportation workers. In addition, empty cars should be treated with a generous supply of water before moving them in the mines in order to allay the fine dust ever present in such cars. In 1927, Forbes and Emery (*12*), reporting on the sources of dust in bituminous-coal mines, showed that the dust concentrations were materially reduced when the coal which had been blasted from the face was drenched with water, and when water was used liberally on both loaded and empty cars. The use of water to allay the dust stirred up by motor haulage, these investigators found, reduced the dust count from 14 to 2 million particles per cubic foot. In hauling coal with mules, they found that liberal quantities of water decreased the dust count from 17 to 1.2 million particles per cubic foot. It appears, therefore, that wetting down the coal to be loaded, as well as the cars, both full and empty, will reduce the dust breathed by transportation workers to a harmless quantity.

BREAKER WORKERS

The remedial measure for control of the dust in breakers is suggested by the information contained in table 16. The contrast in the dust concentrations found in the wet and dry processes of preparing coal for the market is so great as to require little comment. Since wet-breaker processes are gradually replacing the dry method, the dust problem created by the latter type of breaker appears to be no longer one of major importance.

SUMMARY OF RESULTS UNDER CONTROLLED AND UNCONTROLLED WORKING CONDITIONS IN THE MINES UNDER STUDY

A table which summarizes the results obtained under controlled and uncontrolled working conditions is presented below. The controlled conditions were found in certain places in the mines under

[6] A more detailed discussion of limits of safety appears in the section on "Threshold dosage" in section of part VI.

study. It is apparent that the dust hazard may be greatly lessened, and in some instances adequately controlled, by the extension of methods already employed in the mines.

TABLE 19.—*Summary of results contrasting the dust exposure of anthracite mine workers under controlled and uncontrolled working conditions*

Operation	Average dust concentration in millions of particles per cubic foot of air		Remarks
	Controlled	Uncontrolled	
Loading coal	4–26	[1] 291–1,138	Mechanical loading decreases the dust exposure as indicated.
Drilling	33	568	Wet drilling is effective in reducing the dust concentration. Further reduction obtainable by the use of exhaust ventilation.
Firing charge	40	834	Unless an adequate time interval elapses after firing a charge, miners are found to be exposed to high dust concentrations.
Loading rock	32	636	Wetting the material to be loaded reduces the dust concentration as shown.
Hauling coal in mines	1	17	Wetting coal and empty cars reduces the dust in haulageways.
Preparation of coal	24	380	Wet processing of coal reduces the dust exposure as shown.

[1] The lower average dust concentration is associated with the hand loading of wet coal, while the higher average is found in the hand loading of dry coal.

7. SUMMARY OF REPORT ON WORKING ENVIRONMENT

This report on working environment in anthracite coal mines is based on conditions found in three representative mines in the industry. It constitutes an important part of an investigation of the health of the workers in these mines, made with special reference to the dust hazard.

The preliminary study consisted of a general mine inspection which afforded the information required for presenting a description of the mines and the mining methods employed. An occupational analysis was then made which revealed, among other things, that 53 percent of the workers were employed in getting out coal, work which entailed the most severe dust exposures encountered. In addition, ventilation observations were made in various work places. They showed that temperature and relative humidity were fairly constant throughout all the workings, and were practically the same in each mine during the period studied. Average dry-bulb temperature was 58.5 degrees Fahrenheit, and relative humidity averaged 92 percent. Considerable variation was found, however, in the amount of air movement in different work places. Although each mine was supplied with more than 200 cubic feet of air per minute per man as required by the anthracite mine law, slightly more than 50 percent of the workings surveyed had less than 50 feet per minute air velocity at the face. Many of the work places were practically dead ends, the air movement

being only 10 feet per minute or less. In such places it was found that the ventilation was greatly improved by the use of compressed air.

Nineteen samples of dust which had settled on timbers or ledges at the breathing level in different work places were taken for chemical and petrographic analysis so that information could be obtained concerning the exact nature of the dust to which the workers were exposed. Miners and their helpers were found to be exposed to dust of which about 90 percent was coal, and about 10 percent inorganic matter, the quartz content of this dust being approximately 4 percent. Rock workers, however, breathed dust of which about 93 percent was inorganic matter; the quartz content varied between 27 and 43 percent of this dust. The men in the breakers were found to be exposed to practically the same type of dust as were the miners at the face, while persons engaged in other underground activities were shown to be breathing dust containing about 60 percent coal, and 40 percent inorganic matter, the quartz content being approximately 13 percent.

Measurement of 1,500 particles of dust obtained by sampling the atmosphere in the breathing zone of the workers showed that practically all the particles were less than 4 microns in longest dimension. Eight percent of the particles measured were less than 0.5 micron. Eighty percent were between 0.5 and 1.5 microns. The median size was 0.91 micron.

For determining the dust exposure in different occupations, 300 atmospheric dust samples were obtained. A summary of the results of these determinations is given in table 20.

TABLE 20.—*Summary of occupational dust exposure of workers in 3 representative anthracite coal mines*

Section and occupation	Number of men employed	Number of samples taken	Number of millions of dust particles per cubic foot of air (weighted average)
Underground workers			
Cutting and loading:			
Contract miners and laborers	1,219	114	----------
Chamber miners	----------	----------	480
Breast (pitch) miners	----------	----------	203
Breast (scraper) miners	----------	----------	88
Breast (shaker) miners	----------	----------	55
Company miners	130	----------	(1)
Chute loaders and starters	45	12	291
Shaker loaders	7	4	26
Scraper loaders	12	4	3.8
Scraper loader engineers	31	(2)	[2] 3.2
Opening work (dry process):			
Rock drillers	95	17	241
Rock loaders (muckers and slatemen)	35	2	531
Transportation:			
Motormen, et al.:			
Mine no. 1	166	8	71
Mine no. 2	44	8	[3] 233
Mine no. 3	69	13	3.1
Loader and driver bosses, stablemen, and helpers	10	(2)	[2] 6.9
Shaft, slope, and plane workers, spraggers, and couplers	91	----------	----------
Mine no. 1	----------	7	25
Mines nos. 2 and 3	----------	2	[3] 3.1

Footnotes at end of table.

TABLE 20.—*Summary of occupational dust exposure of workers in 3 representative anthracite coal mines*—Continued

Section and occupation	Number of men employed	Number of samples taken	Number of millions of dust particles per cubic foot of air (weighted average)
Underground workers—Continued			
Other underground workers:			
Ventilation, timbering, and hoisting water sections	276	(2)	[2] 6.9
Superintendence	36	(2)	[2] 2.9
Workers above ground			
Preparation (breaker):			
Dumpers and plane tenders:			
Dry breaker	2	2	71
Wet breakers	7	7	14
Platform men and chippers:			
Dry breaker	7	2	69
Wet breakers	23	7	24
Jig tenders and cone attendants	15	6	11
Slate pickers:			
Dry breaker	40	21	380
Wet breakers	17	5	6.9
Car loaders et al.:			
Dry breaker	8	2	22
Wet breakers	20	4	2.3
All other breaker workers:			
Dry breaker	13	(2)	[2] 331
Wet breakers	49	2	2
All other workers above ground	386	34	2.9
Total	2,853	283	

[1] Dust exposure depends on type of work performed as given in detailed occupational history.
[2] Dust count obtained from samples used for other occupations having similar dust exposure.
[3] Average includes other samples.

It is evident from the data in this table that chamber and pitch mining, chute loading, and rock extraction produce the dustiest working conditions. Chamber miners were found to be exposed to an average dust concentration of 480, pitch miners to 203, and chute loaders working in conjunction with pitch miners, to 291 million particles per cubic foot of air. On account of their presence during the chute loading process, motormen are exposed to an average dust concentration of 233 million particles per cubic foot. Rock workers were found to be exposed to exceedingly high concentrations of dust (531 for loaders, and 241 million particles per cubic foot for drillers). Attention has been called to the high quartz content of the rock dust. Men in other occupations were exposed to varying amounts of dust, ranging from 88 for miners using a scraper loader to less than 3 million particles per cubic foot for persons engaged in superintendence. About 46 percent of the underground employees of the three mines were exposed to more than 200 million particles of dust per cubic foot of air.

The dustiest occupations above ground were found in a dry breaker. Here slate pickers and certain other workers were exposed to about 380 millions of dust particles per cubic foot. In wet breakers, how-

ever, the highest average dust count for any group of workers was found to be 24 million particles per cubic foot.

When the data as a whole were considered, irrespective of underground or surface activities, it was found that 37 percent of the workers were exposed to more than 200 million particles per cubic foot; 38 percent to less than 26 million particles, and the remaining 25 percent to intermediate dust exposures.

An interpretation of occupational dust exposure as related to the health of the workers is presented in part VI. Finally, methods of minimizing the dust hazard, directed at those activities which contributed the largest proportion of the worker's total dust exposure, have been presented.

IV. PHYSICAL CONDITION OF THE EMPLOYED AND OF THE INCAPACITATED WORKERS

1. PROCEDURE IN ASCERTAINING THE PHYSICAL CONDITION OF THE MEN

During the study 2,711 employees of anthracite coal mining companies were examined in the field office which was quartered in a specially equipped steel railway car loaned by the United States Bureau of Mines. Each day the colliery foreman and the committeemen of the United Mine Workers of America prepared a list of men for physical examination. The men were admitted for examination in groups of 5 or 6, but were interviewed individually. When necessary one of the committeemen (a representative of the United Mine Workers) acted as interpreter. The workers were examined as they appeared, without reference to occupation, age, or physical condition.

OCCUPATIONAL HISTORY

The interview began by ascertaining all of the worker's industrial experience. A reproduction of an occupational history sheet developed for use in this study illustrates the nature of the data recorded. It revealed: (*a*) The total number of years the individual had worked; (*b*) whether he had been exposed to dust; and (*c*) the nature and duration of each occupational exposure, and the industry in which it occurred. The employee's estimate of the amount of time lost on account of unemployment was also recorded. In the column headed "Remarks", certain qualifying statements were added when necessary.

PAST MEDICAL HISTORY

Information regarding intimate contact with tuberculosis, and the examinee's past respiratory illnesses were recorded in order to

afford a basis for judging the cause, nature, and extent of pulmonary changes found. The past medical record obtained is also shown. Frequent colds were recorded only when they were of such severity as to cause loss of two or more days from work.

OCCUPATIONAL AND PAST MEDICAL RECORD

NAME Walroy, F. R. NO. 000 PRES. AGE 51 MINE X DATE

AGE BEGAN WORK 14 NO. YRS WORKED 37 COUNTRY BIRTH U. S. A. RACE

	OCCUPATION	INDUSTRY	NO. YRS. IN. HARD COAL MINES	OTHER DUSTY	NON-DUSTY	REMARKS
PRES.	Contract miner	H. coal	28			(Breast, 4 yrs. Gangway, 24 yrs)
PREV. 1	Company laborer	" "	3			
2	Ordinary seaman	Merchant marine			1	
3	Mule driver	H. coal	2			
4	Door tender	" "	½			
5	Slate picker	" "	2			Dry breaker
6					½	Estimated time idle.
7						
8						
9						
10						

PAST MEDICAL (INSERT DATE OF ILLNESS IF POSITIVE HISTORY IS RECORDED).

T. B. CONTACT (F OR P) 0 WHEN --
T. B. 0 INFLUENZA 1918 (2 weeks) SYPHILIS 0
TYPHOID FEVER 0 FREQ. COLDS + Since 1928 SCARLET FEVER 0
PNEUMONIA 0 BRONCHITIS + Since 1928
PLEURISY 1932 CHR. RHEUM. 0
OPERATIONS 0

PRESENT CHRONIC ILLNESS OR COMPLAINTS (INSERT DATE OF ONSET WHEN POSITIVE)

FREQ. COUGH + PRODUCTIVE slight CHAR. OF SPUTUM mucopurulent
NIGHT SWEATS 0 WEAKNESS 0 DYSPNOEA 2+gradually inc. since 1927.
PAIN (see below) LOCATION MINERS' ASTHMA ?
OTHER COMPLAINTS Pain+ sacro-iliac region.

OCCUPAT. RECORD TAKEN BY W.R.J.
PAST MED. RECORD TAKEN BY W.R.J.

FIGURE 16.

PRESENT CHRONIC COMPLAINT OR ILLNESS

Present complaints of ill heath were recorded in the manner indicated, and were found useful when corroborated by evidence obtained from the physical examination. The main symptomatology of anthraco-silicosis was derived from the analysis of the recorded complaints.

PHYSICAL EXAMINATION

The examinee was stripped to the waist and a careful examination was made, particular attention being given to the chest. The examination included a record of height, weight, and recent gain or loss of weight. The circumference of the chest was measured at the level of the nipple line at rest, full inspiration, and full expiration. As an additional guide for roentgenological technic, the antero-posterior diameter of the chest at full inspiration was recorded. General appearance and physical development were noted. The nose and throat were inspected, and evidence of mouth breathing was recorded. The blood pressure was taken with a standard mercury sphygmomanometer with the examinee seated. Each worker was subjected to a uniform test in which one foot was placed upon a chair, and the body raised to an erect position 25 times in 30 second. If pathological conditions contraindicated its use, the test was not given. Pulse and respiratory rates were taken before, immediately after, and 2 minutes after the prescribed exercise.[7] The chest examination consisted of careful inspection, palpation, percussion, and auscultation of the heart and lung fields. On completion of the physical examination, a final summary of chest findings was recorded. The examination of the abdomen and extremities was omitted except for noting such facts as ankylosis, loss of limb, clubbing of the fingers, and hernia.

ROENTGENOLOGY

One of the large compartments of the field car was converted into a dark-room for the fluoroscopic work. When the physical examinations were completed on 5 or 6, the men were assembled in this room for roentgenological study with a standard portable X-ray unit. Fluoroscopy of the chest was the first step in this examination. It included lateral, oblique, and postero-anterior fluoroscopy. By leaving the X-ray picture to be taken after other methods of examination had been completed, it was possible to judge better the kilovoltage and time of exposure necessary to secure the best roentgenograms. The X-ray pictures of the chest were made at a distance of 40 inches. The time of exposure varied from 0.5 to 1.5 seconds, depending on such factors as thickness of the chest and chest wall,

[7] The test was employed to indicate whether the worker was physically fit for arduous tasks through the knowledge it afforded of cardiac and respiratory response to exercise. The interpretation of results as regards decreased capacity for work involved the consideration of several factors. For instance, age, weight, present occupation, whether the test was made before or after a day's work, and the extent to which the examinee cooperated, had to be considered. Absence of circulatory embarrassment was indicated when the pulse rate was within the normal range before exercise and when it returned to the normal pulse range within a 2-minute rest period following the exercise. Absence of respiratory embarrassment was indicated when the respiratory rate was within the normal range before exercise and returned to the normal range following a two-minute rest interval, and with the expiratory phase not unduly prolonged. (A continued high respiratory rate with the expiratory phase of respiration unduly prolonged was commonly found among those suffering from anthraco-silicosis.)

and the amount of pulmonary fibrosis found on clinical examination and fluoroscopy.

DIAGNOSIS

The final diagnosis was made after a critical review of all the clinical and roentgenological findings in each case. The diagnosis indicated whether the physical findings were essentially negative, or whether first-, second-, or third-stage anthraco-silicosis had developed. It also included a clinical estimate of any decrease in the man's capacity for work. Pulmonary infection when present was also recorded. If the clinical evidence was sufficiently suggestive of tuberculosis, the pulmonary infection was so identified.[8]

For the purpose of analyzing the clinical findings, all the men examined were classified according to the diagnosis, viz., whether essentially negative from the standpoint of anthraco-silicosis, or whether the disease was present in its first, second, or third stage.[9] Comparison of clinical findings was also made with a control group composed of 361 men selected from those classed as "essentially negative" who had had little dust exposure (less than 5 million particles per cubic foot of air). The controls represented workers largely of the same racial extraction, of similar age distribution, and in the same general economic status as the other men examined. The men with anthraco-silicosis, particularly those in the second and third stage of the disease, were somewhat older.

TABLE 21.—*Percentage distribution by age of the control group in comparison with all other men examined, and with all diagnosed as having anthraco-silicosis*

Groups under comparison	Number of men examined	Percentage of men in age group—				
		Under 30	30–39	40–49	50–59	60 and over
Control group	361	29.6	29.8	22.6	11.3	6.6
All other men examined	2,350	24.2	26.2	31.1	14.0	4.6
All diagnosed anthraco-silicosis	616	0	9.9	48.9	31.0	10.2

At the time of examination those in the essentially negative group were not presenting changes indicative of anthraco-silicosis. The findings for this large group more nearly paralleled those of the controls than of the early anthraco-silicotics.

[8] The term "clinical tuberculosis" as used in this report is a provisional diagnosis based on the presence of at least four of the more common symptoms associated with fibroid phthisis in the adult, exhibited by an individual having a history of intimate contact with an active case of pulmonary tuberculosis, or a highly suggestive past medical history, whose general appearance is that of an unhealthy person and whose chest roentgenogram is typical of pulmonary infection. Symptoms considered as commonly associated with the condition are progressive loss of weight, weakness, night sweats, hemoptysis, chest pain, low-grade fever, crepitant rales which persist after coughing, indefinite epigastric discomfort, and hypotension.

[9] The classification of anthraco-silicosis without infection used in this report follows the classification for silicosis presented by the Committee on Pneumoconiosis of the American Public Health Association, October 1933.

SUPPLEMENTAL OBSERVATIONS

Because certain factors, as for example, pulmonary infection, may alter the course of pathology, and on account of the finding, discussed later, that anthraco-silicosis tends to progress after cessation of heavy exposure, it seemed important to examine a number of disabled former miners. A group of 135 disabled ex-miners was selected for study from among more than 1,000 men referred by practicing physicians, health and relief agencies. The basis for selection was as follows:

(*a*) The individual must have been an anthracite worker throughout the greater part of his working life, and at no time engaged in any dusty trade other than anthracite coal mining.

(*b*) His disability must have been of moderate or marked degree, and have been due primarily to respiratory embarrassment.

(*c*) Men representing different age groups and different amounts of exposure to anthracite coal dust were selected.

(*d*) None was accepted on whom a definite laboratory diagnosis of pulmonary tuberculosis had been made.

The first three bases of selection appear to be self-explanatory. The fourth basis was considered necessary because the problem was complicated by the entrance of infection into the picture. The inclusion of individuals with a known diagnosis as to type of infection might have yielded biased data. However, by accepting only those upon whom no such diagnosis had been made, it is obvious that conclusions concerning the role played by tuberculosis are more likely to represent under than over-statements. While a few individuals were accepted who showed from study of their condition during hospitalization that causes other than anthraco-silicosis were at least partly responsible for their disability, such facts were given consideration.

The ex-miners were given the same type of clinical examination as the active workers, except that it was not possible to subject many of them to any exercise test on account of their physical condition. Hospitalization afforded an opportunity for securing temperature records and laboratory data. The laboratory findings included reports upon the blood, sputum, and urine. Blood examination included total red and white cell counts, hemoglobin estimations, differential and nonfilament counts, erythrocyte sedimentation rate determinations, and Wassermann (and Kahn or Kline) reactions. In the sputum examinations the general characteristics such as consistency, color, and odor were noted; direct smears were examined; antiformin concentrates were studied, cultured, and injected subcutaneously into the groin of the guinea pig. Routine gross and microscopic examinations of the urine were also made.

Due to the fact that a significant number of anthracite workers were diagnosed as suffering from anthraco-silicosis plus clinical pulmonary tuberculosis, plans were made to study a limited number of pneumoconiotic patients at the State tuberculosis sanatorium in order to learn more about the course of the disease, and to compare the clinical picture presented by such individuals with that shown by persons with pulmonary tuberculosis who had had no appreciable exposure to dust. In this institution 31 men over 35 years of age had been diagnosed as having pneumoconiosis and pulmonary tuberculosis. Ten of these 31 men had been anthracite coal miners for whom a diagnosis of anthraco-silicosis plus pulmonary tuberculosis was considered established. The remaining 21 had been sand blasters, granite cutters, foundry workers, etc. Data were obtained on a group having a similar distribution as regards age, race and nationality, and economic status, consisting of 32 men who had had no occupational exposure to harmful dust.

PATHOLOGICAL STUDY

A limited number of lungs secured at autopsy by physicians in the anthracite region were forwarded to the Public Health Service for study. The examination of these specimens included, whenever possible, an X-ray picture of the lungs without inflation, a complete pathological examination, and a chemical examination to determine the total amount of silica present.

2. MEDICAL FINDINGS

Of the 2,711 employed workers examined, 616 or 22.7 percent were diagnosed as having anthraco-silicosis. The number in stage 1 was 510 (18.8 percent of the number examined); in stage 2, 82 (3.0 percent); and in stage 3, 24, or 0.9 percent.

Classification of the men according to whether or not they presented evidence of anthraco-silicosis was complicated by the borderline or doubtful cases. A much larger number of men were found in the first stage of the disease than in the more advanced stages (stages 2 and 3). Many in the first stage presented no subjective evidence of disease, and were regarded as early anthraco-silicotics because they showed definite if but slight objective evidence of the disease. The positive medical findings were based on the observations recorded on these 616 men, as well as on the group of 135 totally disabled former anthracite workers.

PAST HISTORY OF ILLNESS

The 616 employed men having anthraco-silicosis reported attacks of pleurisy, pneumonia, and severe colds more often than the control group, as is shown in table 22.

TABLE 22.—*Number and percentage of employed anthracite workers reporting tuberculosis contacts and past respiratory illnesses in each group specified*

Past medical finding	Percentage of men examined					Number of men examined				
	Control group	Group diagnosed essentially negative	Anthraco-silicotics in—			Control group	Group diagnosed essentially negative	Anthraco-silicotics in—		
			Stage 1	Stage 2	Stage 3			Stage 1	Stage 2	Stage 3
Negative [1]	57.0	57.0	46.3	40.2	54.2	206	1,193	236	33	13
Tuberculosis contact	6.9	5.7	7.2	4.9	4.2	25	120	37	4	1
Pneumonia	12.2	10.2	14.7	13.4	8.3	44	213	75	11	2
Pleurisy	8.0	7.5	11.7	23.2	12.5	29	158	60	19	3
Influenza	25.2	26.6	33.0	31.7	25.0	91	557	168	26	6
Bronchitis, colds [2]	5.0	5.8	9.4	12.2	16.7	18	121	48	10	4
Total number examined						361	2,095	510	82	24

[1] For any of the diseases or conditions listed.
[2] Causing disability for 2 or more days.

Among the 135 former anthracite coal workers who were totally disabled, these respiratory illnesses were reported as occurring from 2 to 5 times as often as in the group of employed men diagnosed as having anthraco-silicosis, and from 4 to 10 times as often as in the control group.

SYMPTOMATOLOGY

The cardinal symptom of anthraco-silicosis as observed in the men examined was shortness of breath, frequently associated with productive cough. The more advanced cases often complained of weakness, chest pain, gastric disturbances, and hemoptysis. Fever and night sweats, however, were seldom mentioned.

TABLE 23.—*Number and percentage of employed anthracite workers giving complaints of ill health in each group specified*

Present complaint	Percentage of men examined					Number of men examined				
	Control group	Group diagnosed essentially negative	Anthraco-silicotics in—			Control group	Group diagnosed essentially negative	Anthraco-silicotics in—		
			Stage 1	Stage 2	Stage 3			Stage 1	Stage 2	Stage 3
Negative [1]	81.4	78.3	53.5	30.5	16.7	294	1,640	273	25	4
Dyspnoea	6.4	9.5	34.1	63.4	83.3	23	200	174	52	20
Weakness	.8	.8	4.7	13.4	16.7	3	17	24	11	4
Cough	2.2	4.5	16.7	32.9	54.2	8	94	85	27	13
Chest pain	1.7	1.8	5.9	18.3	12.5	6	37	30	15	3
Other pain	4.7	4.8	4.7	4.9	8.3	17	101	24	4	2
Other complaints	8.3	6.9	5.7	15.9	4.2	30	144	29	13	1
Total number examined						361	2,095	510	82	24

[1] For any of the complaints listed.

PHYSICAL FINDINGS

In comparison with the control group, the objective sign most frequently observed among the anthraco-silicotics was dyspnoea. In early cases a functional exercise test was frequently required to demonstrate dyspnoea. Other signs commonly presented by the men affected were prolonged expiration, change in contour of the chest, decreased chest expansion, clubbing of the fingers, change in breath sounds, altered fremitus, and impaired resonance.

TABLE 24.—*Percentage of employed anthracite workers examined, and of disabled former workers in the industry, having specified physical impairments as compared with the control group*

Physical findings	Control group	Anthraco-silicotics			
		Employed workers in—			Disabled former anthracite workers
		Stage 1	Stage 2	Stage 3	
Dyspnoea (after functional test)	1.6	41.2	71.7	95.8	[1] 100.0
Asthenic or cachexic general appearance	4.0	11.6	29.0	33.0	97.0
Asthenic or emphysematous type of chest	8.7	25.0	46.0	70.0	74.8
Chest expansion (average in inches)	3.1	2.7	2.3	2.2	1.8
Impaired resonance	8.3	69.0	85.4	91.9	92.7
Changed breath sounds	26.5	85.1	92.7	96.0	95.0
Altered fremitus	6.9	62.8	83.0	91.9	86.8
Persistent râles:					
Crepitant	.3	7.1	13.4	25.0	25.9
Subcrepitant	3.3	19.4	30.4	37.5	51.8
Sibilant	1.4	16.6	29.3	45.8	36.8
Sonorous	1.4	5.8	15.8	12.5	7.0
Prolonged expiration	.6	18.2	28.0	45.8	(2)
Clubbed fingers	4.1	29.0	34.1	16.7	76.7
Enlarged heart	3.3	6.1	8.5	8.3	24.0
Cyanosis	(3)	(3)	(3)	16.0	40.0
Emphysema [4]	.8	26.7	39.1	70.9	100.0
Impaired function of the diaphragm [4]	17.2	76.5	85.3	95.8	96.3
Number of men examined	361	510	82	24	135

[1] With or without exercise.
[2] Unable to exercise any; hence data are not comparable.
[3] No comparable data.
[4] As determined by X-ray examinations.

Those having infection complicating the condition, and those markedly or completely disabled showed these changes in a more marked degree, and frequently evidenced loss of weight and strength, and cyanosis; persistent râles were invariably found, and often there was evidence of cardiac impairment. Each person diagnosed as having anthraco-silicosis presented at least four of these signs as well as other positive evidence revealed by the history and the X-ray examination.

ROENTGENOLOGICAL FINDINGS

Definite lung changes were demonstrated roentgenologically in all cases diagnosed as anthraco-silicosis. Occasionally these changes were slight among persons definitely disabled, and sometimes marked changes were exhibited in workers showing only slight disability.

As a rule, however, the lung changes revealed by X-ray examination corresponded with the amount of physical impairment found.

Decrease in the motility of the diaphragm as demonstrated by fluoroscopy was frequently observed. This malfunction, varying from slight to practical fixation, increased with the severity of the pulmonary pathology. Not infrequently adhesions between the visceral and diaphragmatic pleura could be seen. The usual changes, readily detected on examination of X-ray film, could also be noted by fluoroscopy, though not so well.

In every case diagnosed anthraco-silicosis, film examination indicated generalized fibrosis, and frequently concomitant emphysema. The fibrosis was manifested by an increase in the usual linear lung markings to granular, nodular, coalescing nodular, and conglomerate shadows. The evidence of emphysema increased with the density of the shadows denoting fibrosis. It was usually more pronounced in the lower lung fields, but it could often be demonstrated in other areas. While evidence of fibrosis was, as a rule, more readily interpreted than emphysema, the latter was occasionally more prominent than the indications of fibrosis would lead one to expect.

In practically all cases of anthraco-silicosis the hilar shadows were abnormal as to size and density. Changes in the position and size of the heart, and traction on the trachea with other evidence of mediastinal distortion were not infrequently noted in the more advanced cases (stages 2 and 3).

Cases of anthraco-silicosis in which infection was diagnosed usually showed less symmetrical lung markings. In many cases this change was similar to that commonly regarded as due to pulmonary tuberculosis. The individual shadows were usually less discrete or defined in those cases of anthraco-silicosis in which other signs of infection were noted.

FILM INTERPRETATION

Although a diagnosis of anthraco-silicosis cannot be based on film findings alone, adequate diagnosis requires a good chest film. The terminology used to describe the shadows observed on the film is given in figure 17. When these terms are used, the final X-ray report expresses the extent and character of the shadows observed. In the absence of knowledge of other facts about the individual, such information is inadequate for a diagnosis. For example, general fibrosis 1+ (granular phase with symmetrical distribution of markings) in itself does not constitute a diagnosis of early anthraco-silicosis. However, such an X-ray report on a person with a history of exposure to dust, negative medical history as regards respiratory infection, and the absence of clinical evidence of pulmonary infection as determined by physical examination, would afford evidence which aids in establishing a diagnosis of early anthraco-silicosis.

Figure 17 shows the overlapping of the linear, granular, nodular, and conglomerate phases. Exaggerated linear markings alone are indicative of changes not infrequently found in healthy lungs. Age, and the respiratory infections experienced by the average adult in some cases may cause even a beginning decrease in linear marking, and the appearance of beading or granular shadows.

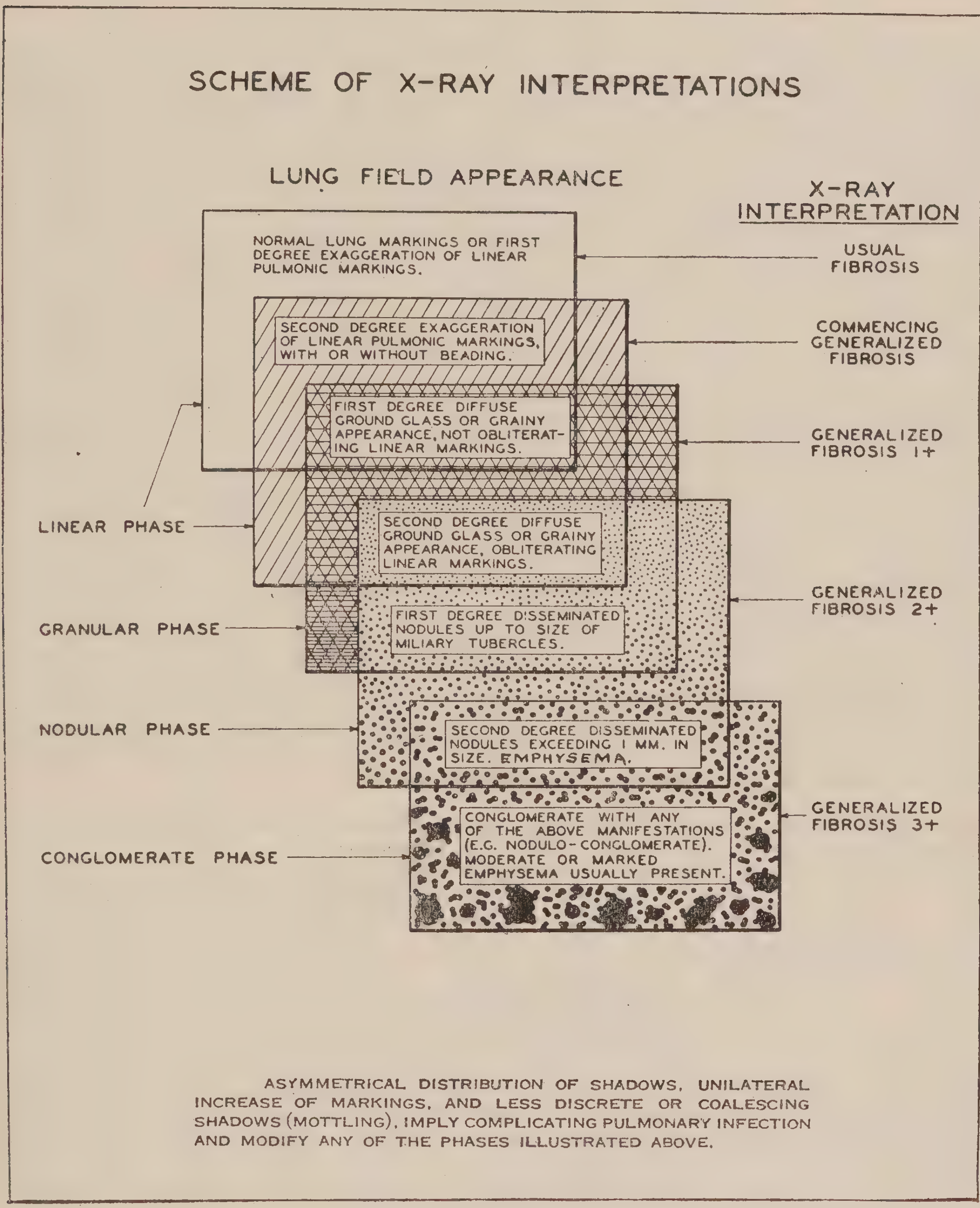


FIGURE 17.

Early generalized pulmonary fibrosis (the borderline case) is generally represented by the granular phase, with a beginning decrease in the usual linear markings. Likewise, the borderline case between general fibrosis 2 and general fibrosis 3 is generally represented by the coalescing nodular phase in which evidence of emphysema is not marked.

139428—35——5

It will be noted that asymmetrical markings, unilateral increase in shadows, and shadows with irregular and less discrete edges imply infection, and modify any of the four phases. The extent to which infection is responsible for changes in X-ray film markings can be judged only through careful consideration of all pertinent clinical and historical data.

DISABILITY FINDINGS

Disability ratings were made in order to obtain an index of the worker's degree of disability if any existed. Contributory causes were taken into consideration. The rating was based on a clinical estimate of the employee's decreased capacity to perform strenuous work. Different degrees of disability were classified as slight, moderate, or marked. From the nature of the criteria set up for slight disability, this degree may be regarded as a decreased capacity for which the man can still compensate. In other words, maximum capacity for work is decreased, but the usual amount of work which the person is capable of doing may not be materially affected.[10]

About 63 percent of those having anthraco-silicosis showed evidence of disability, as compared with 9.7 percent of the men in the control group. The excess disability among the anthraco-silicotics may be assumed to be attributable to the direct and indirect effects of dust inhalation. If slight disability for which the worker is able to compensate is disregarded, it is found from table 25 that moderate and marked degrees of disability handicapped 20.9 percent of those with anthraco-silicosis and only 1.7 percent of the men serving as controls. Moderate and marked degrees of disability were largely confined to the men having second- or third-stage anthraco-silicosis.[11]

TABLE 25.—*Number and percentage of employed workers examined showing physical impairment sufficient to decrease capacity for work in each group specified*

Classification of workers according to the diagnosis made	Percentage of persons showing physical impairment [1]			Number of persons showing physical impairment [1]			Number of men examined
	Slight, moderate, or marked	Moderate or marked	Marked	Slight, moderate, or marked	Moderate or marked	Marked	
Control group	9.7	1.7	0.3	35	6	1	361
Group essentially negative	9.4	1.3	.2	196	28	4	2,095
Anthraco-silicotics	63.4	20.9	6.2	391	129	38	616
Stage 1	56.4	10.2	2.3	288	52	12	510
Stage 2	96.4	67.0	11.0	79	55	9	82
Stage 3	100.0	91.7	70.8	24	22	17	24

[1] Sufficient to decrease capacity for work.

[10] That a certain number of men in a group of employed persons should be regarded as moderately or even markedly disabled may be explained by the fact that the operators often transferred older men or those partly incapacitated to lighter work for which they were better qualified from a physical standpoint. Furthermore, it was stated by several of the older men who did not perform the exercise test satisfactorily that they were able to continue as regular miners because they worked with younger men who relieved them of some of the more strenuous tasks. A number of other men were able to carry on because they had been promoted to supervisory jobs involving less physical labor.

[11] The single case rated as markedly disabled in the control group had decompensated rheumatic heart disease. Although he came from a sick-bed, he was examined because he was still on the pay roll of the company.

The higher average age of persons diagnosed as having anthraco-silicosis no doubt plays some part in the marked difference in the percentage of men showing disability. Nevertheless, it appeared that anthraco-silicosis with its usual complications is the chief factor producing decreased capacity for work among the men under consideration.

TUBERCULOSIS AS A COMPLICATION [12]

A provisional diagnosis of clinical tuberculosis was made on less than 1 percent of the control group. This diagnosis was made, however, on 6.1 percent of the entire group of 2,711 hard-coal mining employees examined. Among approximately 2 percent of the workers a diagnosis of clinical tuberculosis without anthraco-silicosis was recorded. This percentage corresponds closely with the average prevalence of pulmonary tuberculosis in the general adult male population of the country.[13]

For 124, or 4.6 percent, of the workers examined, a diagnosis of clinical tuberculosis complicating anthraco-silicosis was made. Of the 510 men in the first stage of anthraco-silicosis, 78, or 15.3 percent, were given a diagnosis of clinical tuberculosis complicating anthraco-silicosis. About 43 percent of the men in the second or third stage of anthraco-silicosis appeared to have tuberculosis as a complication. When all groups, with the exception of the control group, were combined, it was found that 19.5 percent of the nontuberculous workers were diagnosed as having some respiratory diseases other than tuberculosis. In the control group only 6.4 percent had nontuberculous respiratory disease.

OBSERVATIONS AT A STATE TUBERCULOSIS SANATORIUM

The clinical picture presented by men having pneumoconiosis plus pulmonary tuberculosis as observed at a State sanatorium for tuberculosis in Pennsylvania, exhibits certain noticeable differences in comparison with cases of tuberculosis uncomplicated by pneumoconiosis. The two groups of patients observed were similar as regards age distribution.

Shortness of breath was the initial subjective symptom in every case with pneumoconiosis, while it was a late secondary symptom in cases of tuberculosis without pneumoconiosis. Productive cough, chest pains, and loss of weight were the initial symptoms in cases without pneumoconiosis. Although mentioned as often by the group

---

[12] Sputum examinations were not made on the 2,711 coal-mining employees; hence no positive diagnosis of pulmonary tuberculosis can be given on any of these men. Since very little importance may be attached to one negative sputum examination, it was felt that a single examination of this sort was not warranted. Insistence upon 6 to 10 sputum examinations for each worker showing evidence of pulmonary infection would have unduly prolonged the study.

[13] Cf. fig. 21, p. 86.

with pneumoconiosis, they were much later complaints. Hemoptysis was recorded in about 50 percent of each of the two groups; it was commonly an early complaint by those without pneumoconiosis, but a later complaint when the infection was antedated by dust fibrosis. Gastric disturbances were commonly mentioned by both groups. Evidence of respiratory embarrassment was found in both groups, but was more marked among the pneumoconiotics. Bilateral physical and X-ray signs of pulmonary pathology were shown in every case of pneumoconiosis, and were usually present in those with no pneumoconiosis. X-ray films of those having pneumoconiosis presented more massive conglomerate shadows than were found among those not having pneumoconiosis. Evidence of cavity formation was more marked among the latter. About the same proportion was sputum positive in each group (71 to 80 percent). A greater percentage of those with pneumoconiosis showed signs of rapid progress of the disease.

The clinical findings of tuberculosis complicating pneumoconiosis were similar to those found in the cases so diagnosed among the 2,711 employed men examined.

3. LABORATORY FINDINGS ON 135 CASES OF ADVANCED ANTHRACO-SILICOSIS [14]

As previously stated, more than 1,000 disabled men were referred to the Public Health Service for study with special reference to the characteristics of anthraco-silicosis in its later stages. These cases were referred by cooperating agencies in the Scranton and Wilkes-Barre areas.

The basis of selection manifestly eliminated many patients referred for study. A few were found to be working at light outside or relief jobs. Some had formerly worked in other dusty industries and therefore could not be included. Several were excluded on account of a positive diagnosis of pulmonary tuberculosis complicating miners' asthma.

A group of 135 men, representative of anthracite coal miners from the standpoint of age distribution and occupational history were finally accepted for hospitalization. They were markedly disabled on account of respiratory embarrassment, being physically unfit to pursue any gainful occupation. However, on none of them had a positive diagnosis of pulmonary tuberculosis been established.[15] All of these men were found to be suffering from anthraco-silicosis. When the same standard of diagnosis was applied as was used in the case of workers having pulmonary infection, it was found that 54

[14] By H. O. Proske, senior medical technician (bacteriology).

[15] In a group of 187 anthraco-silicotics referred to the Public Health Service by one agency, 10 were excluded because tubercle bacilli had been found in their sputum. Thirty-eight of the remaining 177 were accepted for hospitalization, and the sputum of 4 of these 38 men was found to contain tubercle bacilli.

of the 135 disabled men, or 40 percent, could be considered as having clinical tuberculosis plus anthraco-silicosis.

The discussion of past medical histories and physical findings in the group hospitalized has been considered in the previous section together with the analysis of such findings observed upon the 2,711 men employed in the anthracite industry. Observations made upon the hospitalized group which were not made upon the anthracite workers are briefly summarized as follows:

Temperature.—Twelve or 8.8 percent of those hospitalized were found to have daily temperatures above normal, ranging from 99.2 to 102.5° F.

Sputum.—Thirteen of the 135 disabled men, or 9.6 percent, proved positive for tuberculosis. Their sputum contained acid-fast bacilli which produced lesions typical of tuberculosis when injected into guinea pigs.

Blood.—No striking changes were found in the erythrocyte and leucocyte counts and hemoglobin determinations. Polycythemia which has been reported as associated with pneumoconiosis was not observed in this series. The differential leucocyte count showed no appreciable abnormality except a rather uniform increase in nonfilament neutrophils. There was a definite tendency to an increased erythrocyte sedimentation rate. An increase in nonfilament cells and accelerated blood sedimentation paralleled each other, and they were found in the presence of both nontuberculous and tuberculous complicating infections of a chronic nature. Positive Wassermann reactions were reported on only 3 in this entire group.

Urine.—About one-fourth of the completely disabled group were shown to have renal pathology as evidenced by such signs as albumin, granular casts, and red blood cells.

4. REPRESENTATIVE CASE HISTORIES

A number of case histories and accompanying chest films are submitted as representative of the clinical and roentgenological findings obtained in the study of employed, and of incapacitated anthracite workers. The historical and clinical facts presented in each case are those on which the diagnosis was based. These case reports again emphasize the need for basing the diagnosis on all the findings. That an adequate diagnosis cannot be made from the X-ray film alone nor from any other single item of information is illustrated by comparison of the case reports and chest films of miners at work with those completely disabled.

The role played by infection in the later stages, as judged by the evidence of its presence, appears to be of great importance in the progress of the disease. It is regretted that this report could not include a series of examinations of the same individuals to show the

progress of the disease in detail. Only two case reports of this sort are available in the present study. One of these shows the changes which developed in a period of 2 years after complete disability was manifested (case D–51), and the other illustrates the rapid progress of the disease when infection complicated early-stage anthraco-silicotic fibrosis (case D–300: 5). In this case a period of about 8 months intervened between the first and second examination.

In spite of the very limited amount of information on the progress of the disease in individual cases, it is apparent from the representative case histories and from the other data available that the pathological changes are largely the result of long-continued exposure to dust.

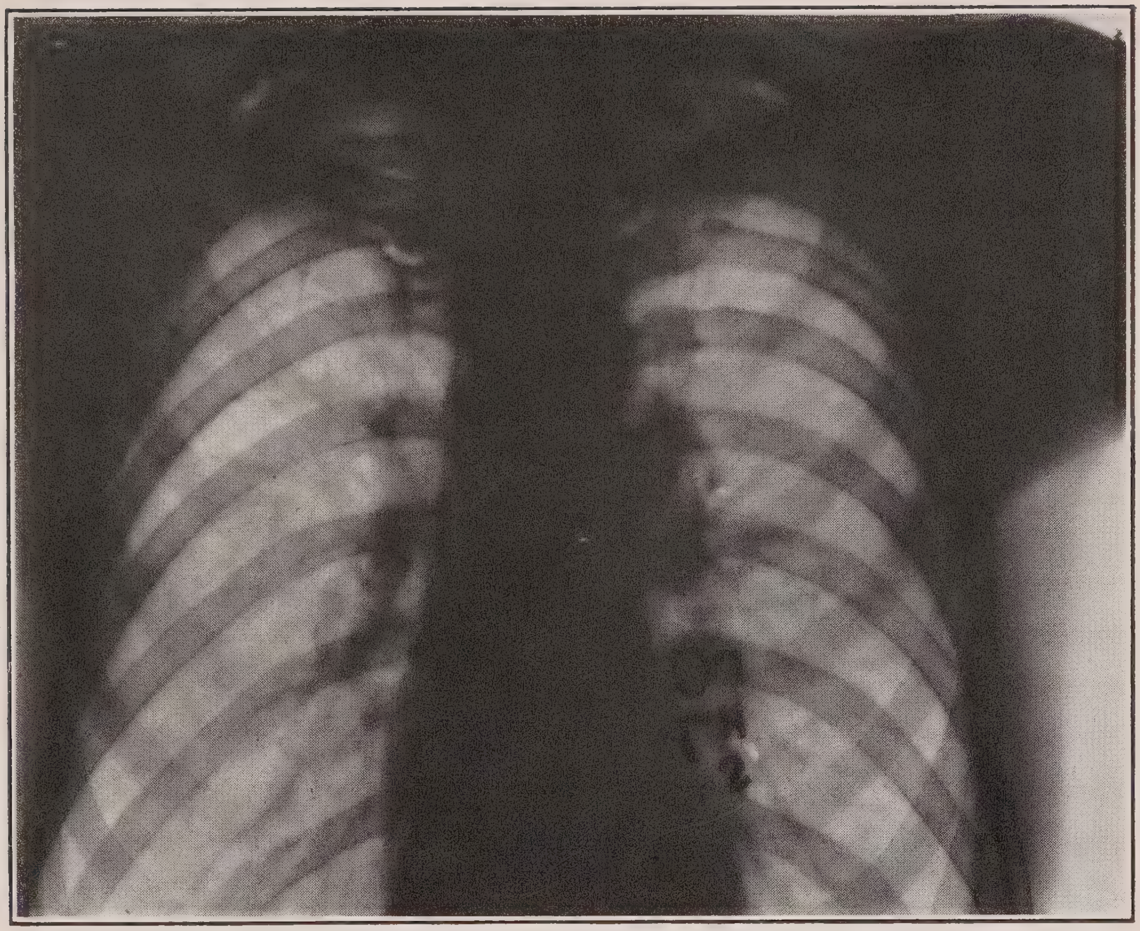


PLATE 1.—CASE C-671. AMERICAN, AGE 50.

Occupational History: Electrician's helper (city), 8 years; assembler in electric motor works, 2 years; machinist in knitting mills, 2 years; mine electrician, 21 years, about half the time underground.

Estimated Dust Exposure: (*a*) Weighted average, 2 million particles per cubic foot. (*b*) Million particle years, 42.

Past Medical: Pleurisy in 1930. Gastric trouble (probably peptic ulcer), 1923.

Complaints: Occasional attacks of indigestion.

Physical Examination: Healthy appearance; slender type. Chest, long type with marked evidence of loss of subcutaneous fat. Expansion, 4 inches. No rales or other adventitious sounds. Breath sounds harsh as would be expected in this type of chest. Pulse and respiratory rate returned to normal range after 2 minutes' rest following exercise.

Fluoroscopy: Apices clear; diaphragm regular, and no restriction in motion. Hilar shadows of usual size and density.

Film: Fine branching linear markings extending almost to the outer zones. Usual hilar markings. Drop type heart.

Diagnosis: Essentially negative.

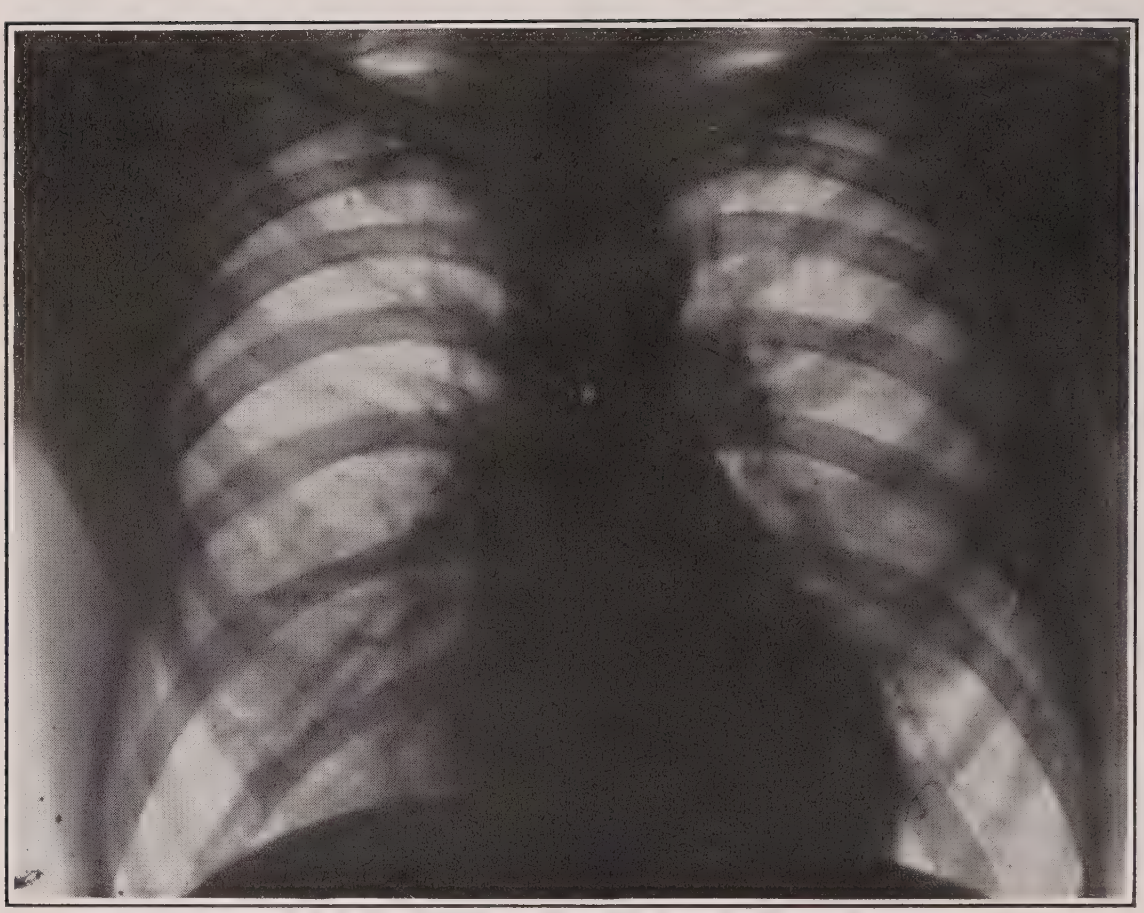


PLATE 2.—CASE C-99. AMERICAN, AGE 29.

Occupational History: Slate picker, 2 years; elevator watchman, 6 years; laborer in a wet breaker, 7 years.

Estimated Dust Exposure: (*a*) Weighted average, 7 million particles per cubic foot. (*b*) Million particle years, 103.

Past Medical: Negative.

Complaints: None.

Physical Examination: Well-nourished, healthy appearing male. Chest expansion, 3½ inches. No evidence elicited of pathological changes in the chest. Pulse and respiratory rate within normal range following exercise test.

Fluoroscopy: Diaphragm regular, and movement good. Usual hilar shadow and lung field markings.

Film: Note slight increase in linear markings confined to the inner zone.

Diagnosis: Essentially negative.

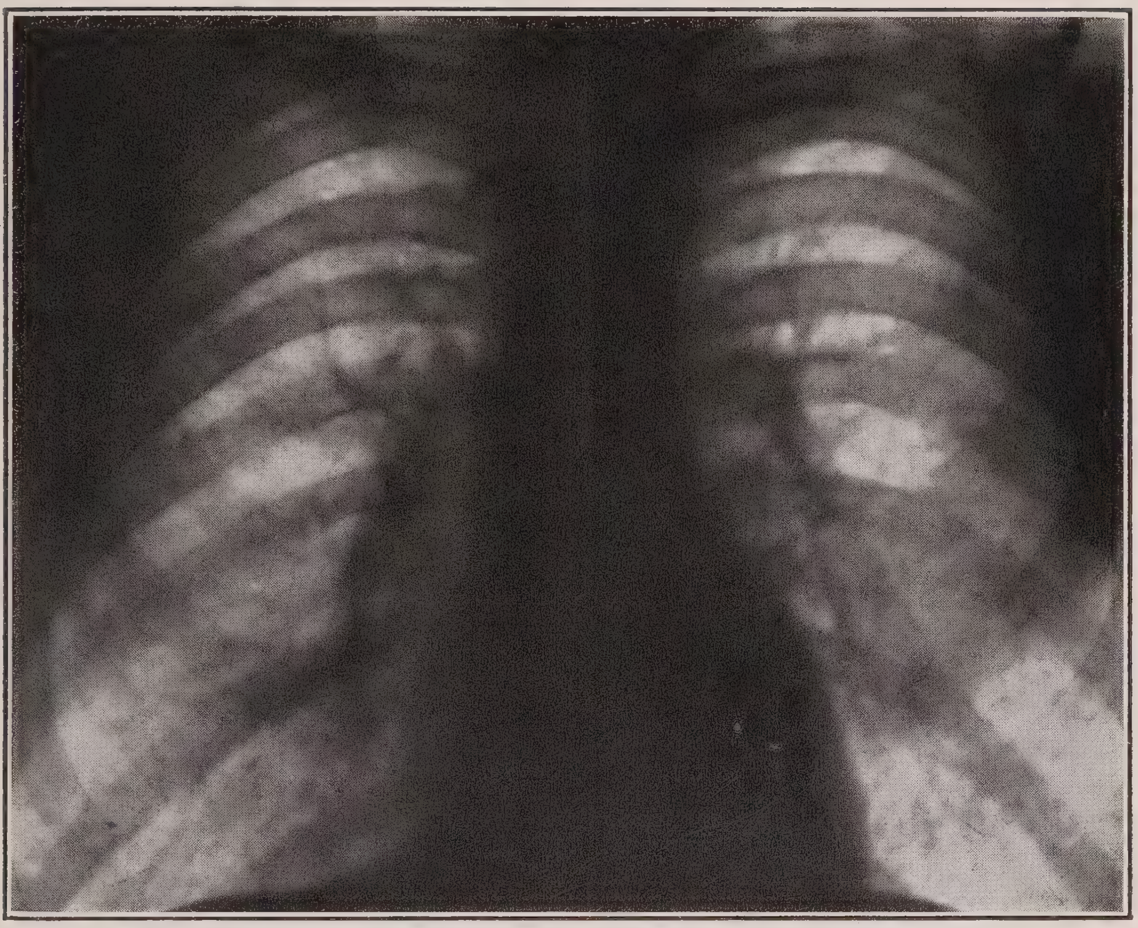


PLATE 3.—CASE C-154. UKRANIAN, AGE 40.

Occupational History: Farmer in old country. Butcher's apprentice and butcher, 4 years; lumberjack in the winter and laborer in paper mill in the summer, 4 years; press mill operator in copper mill, 1 year; outside labor at anthracite mine, 1 year; miner's laborer, 1 year; contract miner, 11 years.

Estimated Dust Exposure. (*a*) Weighted average, 192 million particles per cubic foot. (*b*) Million particle years, 2,498.

Past Medical: Negative.

Complaints: None.

Physical Examination: Healthy and robust-appearing individual. Chest expansion, 4½ inches. No change in fremitus, breath sounds or percussion note. Respiratory rate remained high after exercise test.

Fluoroscopy: Diaphragm regular and movements not restricted. Slight increase in hilar shadow and symmetrical, bilateral, diffuse increase in density over both lung fields.

Film: Note the coarse granular appearance with beginning nodular shadows. Evidence of slight emphysema at both bases. Linear markings practically absent.

Diagnosis: Early anthraco-silicosis. No decreased capacity for work.

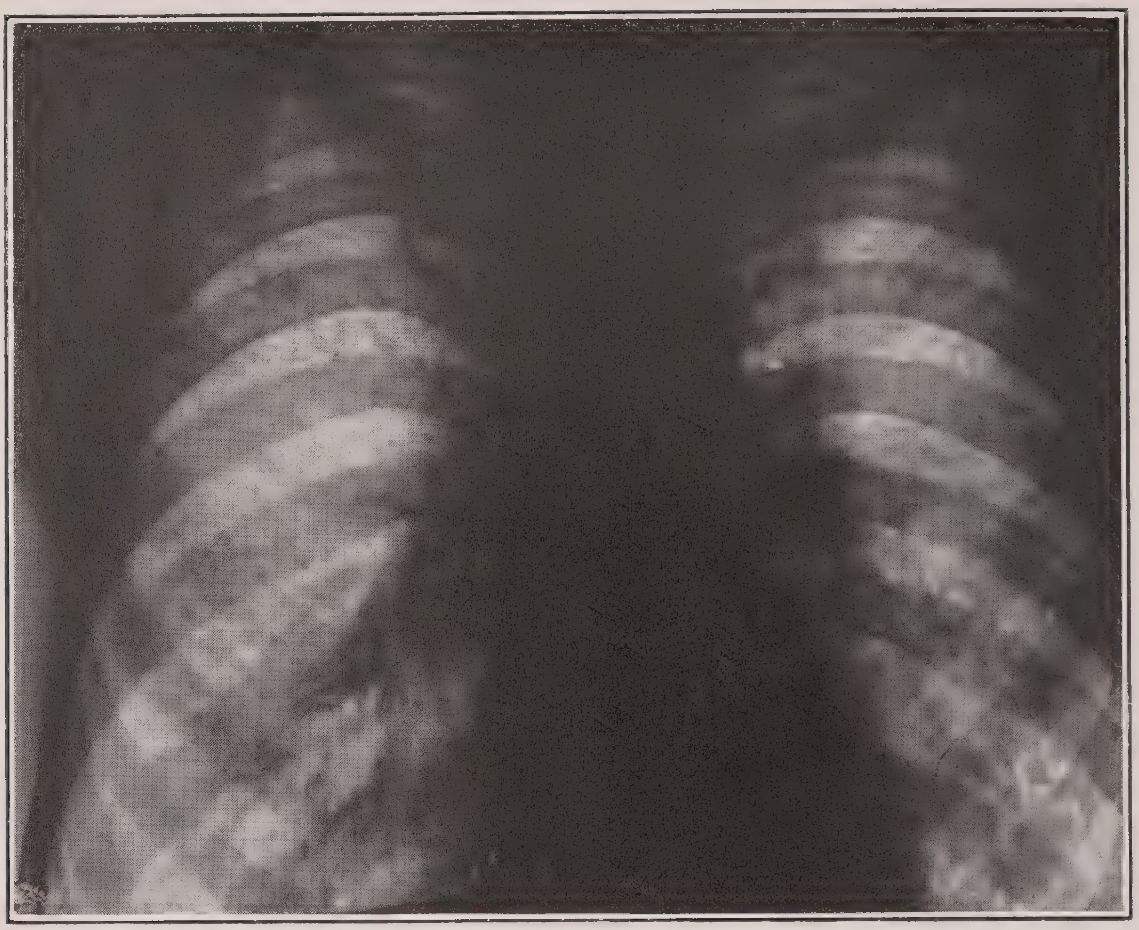


PLATE 4.—CASE C–119. POLE, AGE 48.

Occupational History: Slate picker, 1½ years; mine laborer (underground), 2 years; contract miner, 9 years on rock slope, and past 11 years in breast.

Estimated Dust Exposure: (*a*) Weighted average, 295 million particles per cubic foot. (*b*) Million particle years, 6,632.

Past Medical: Influenza, 1918; pneumonia and pleurisy, 1931.

Complaints: None.

Physical Examination: Well-nourished, healthy appearing individual. Chest expansion 2½ inches. Prominent supra- and infra-clavicular fossae. Harsh breath sounds and slight general decrease in fremitus. Persistent sibilant rales at both bases. Respiratory rate remained elevated after 2 minutes rest following exercise test, with a definite prolongation of expiratory phase of respiration.

Fluoroscopy: Diaphragm regular but decreased motility both right and left. Hilar shadow is increased in size and density. General diffuse increase in density all lung fields.

Film: Note loss of linear markings, uniform nodular appearance of shadows, slight evidence of emphysema.

Diagnosis: Early anthraco-silicosis. No decreased capacity for work.

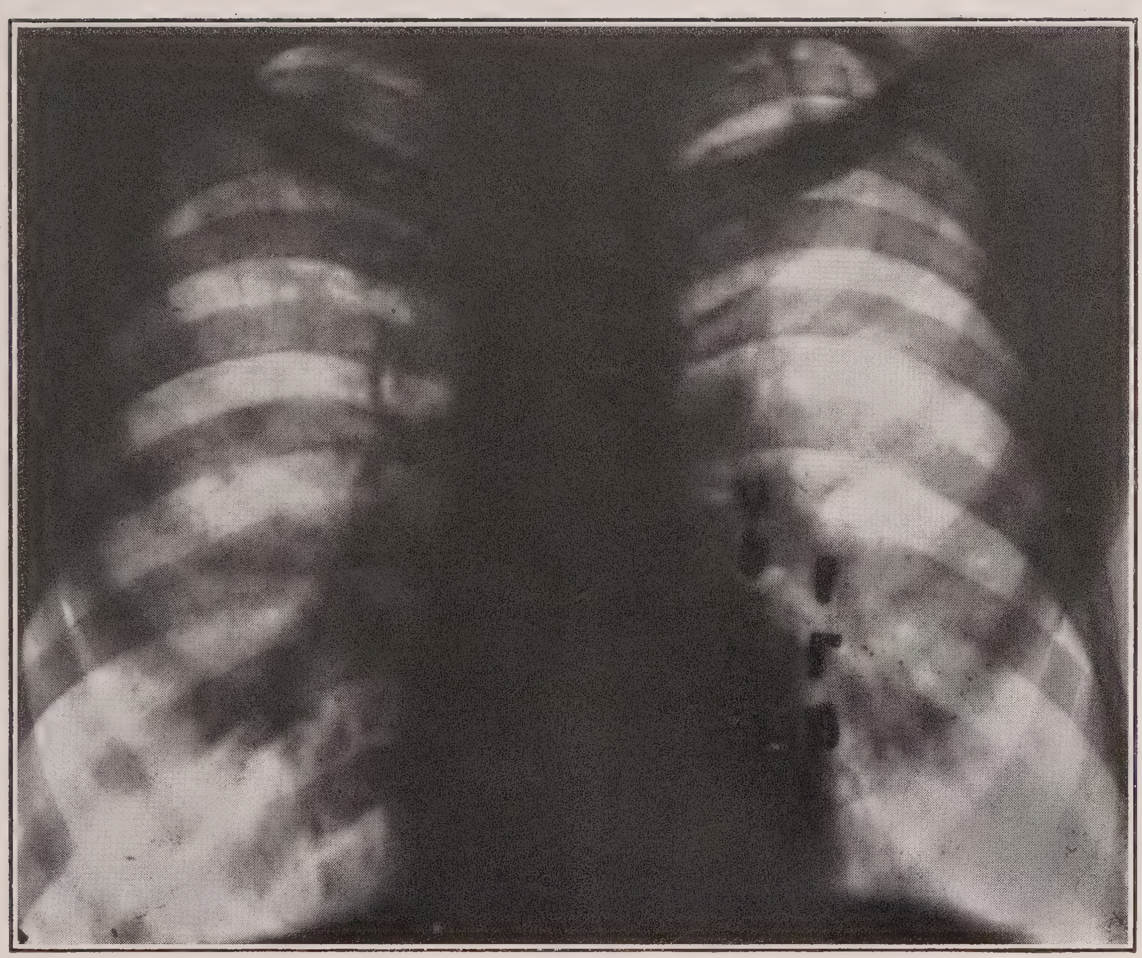


PLATE 5.—CASE B–175. POLE, AGE 46.

Occupational History: Slate picker, 1½ years; company laborer (underground), 8½ years; contract miner, 16 years.

Estimated Exposure: (*a*) Weighted average, 6 million particles per cubic foot. (*b*) Million particle years, 227.

Past Medical: Negative, no excess of respiratory diseases.

Complaints: Does not feel as physically fit as 5 years ago.

Physical Examination: Well-nourished individual. Healthy appearance. Chest expansion, 2½ inches. Slight increase in fremitus over left upper, and few crepitant rales which disappear upon coughing. Breath sounds rather harsh. Respiratory rate remained high after exercise with a tendency to prolonged expiration.

Fluoroscopy: Diaphragm regular in outline but movements markedly restricted. Some increase in density in the upper lung fields, more so on the right.

Film: Note the coarse granular appearance of the upper lung fields with loss of linear markings. Right apex more dense than the left. Emphysema at both bases.

Diagnosis: Early anthraco-silicosis with infection. No disability.

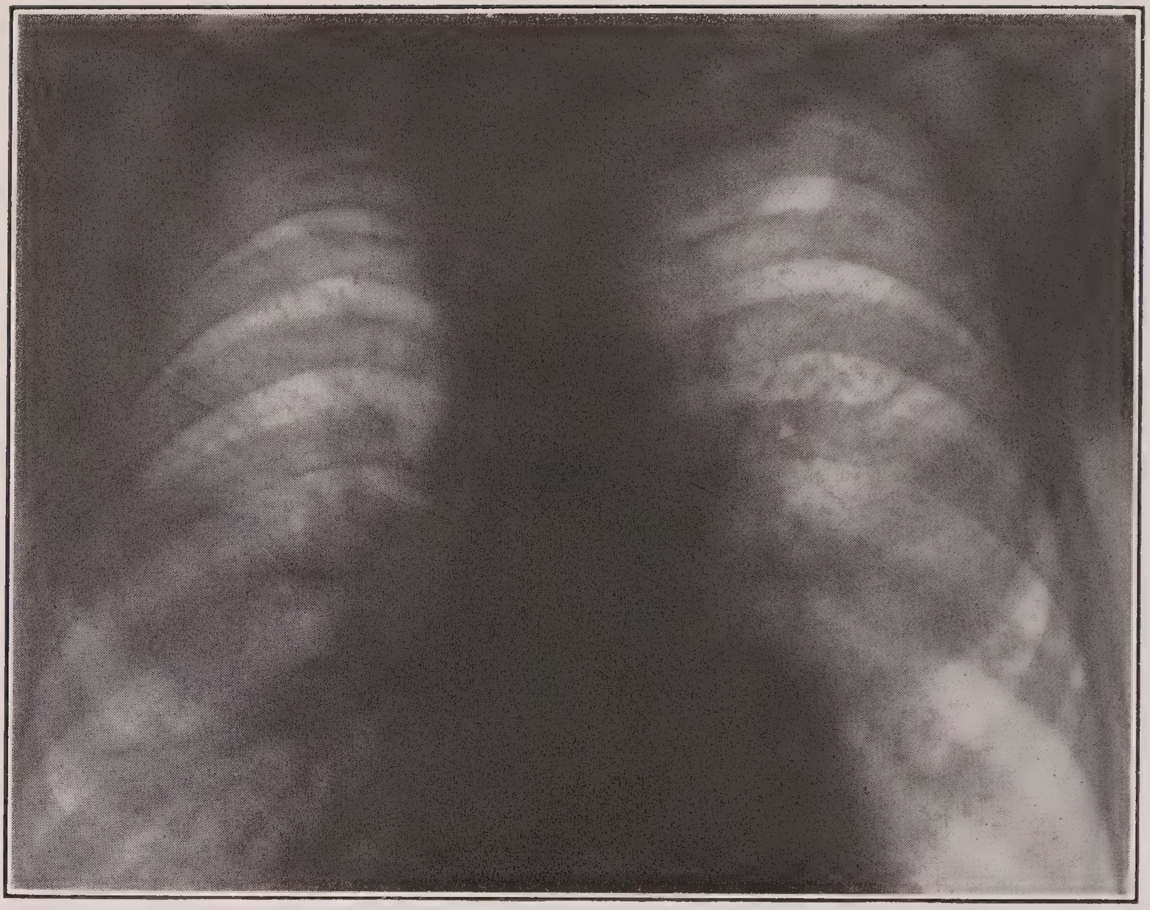


PLATE 6.—CASE B–286. POLE, AGE 57.

Occupational History: Contract miner, 29 years. Other occupations in anthracite, chronologically from beginning of work at the mines: Company laborer, 4 years (underground); company miner, 2 years. Was a farmer in the old country until 22 years of age.

Estimated Dust Exposure: (*a*) Weighted average, 169 million particles per cubic foot. (*b*) Million particle years, 5,929.

Past Medical: Mild influenza, 3 days' duration, 1918. Chronic pleural pains at base of left lung.

Complaints: Weakness, shortness of breath, palpitation on climbing hills, and distress in right chest ("nerves").

Physical Examination: Slender man; 66 inches tall; weight, 148 pounds. Chest expansion, 1¾ inches. Slight cyanosis of mucous membranes; no definite clubbing. Chest medium long, moderate prominence of the supra- and infra-clavicular fossae. Fremitus was increased over the upper portion of both lungs. Percussion note slightly impaired over upper portion of both lungs. Bronchovesicular breath sounds heard over the left upper lobe posteriorly. Persistent subcrepitant and crepitant rales were heard over the upper portions of both lungs.

Fluoroscopy: Diaphragm shows slight limitation in movement, both sides. Moderately dense fibrosis opposite both hila. Moderate generalized fibrosis, both lung fields.

Film: Note increased density central portion, more so on the right side. Scattered emphysema; increase in hilar shadow, both in size and density.

Diagnosis: Anthraco-silicosis. Chronic pulmonary infection; slight disability.

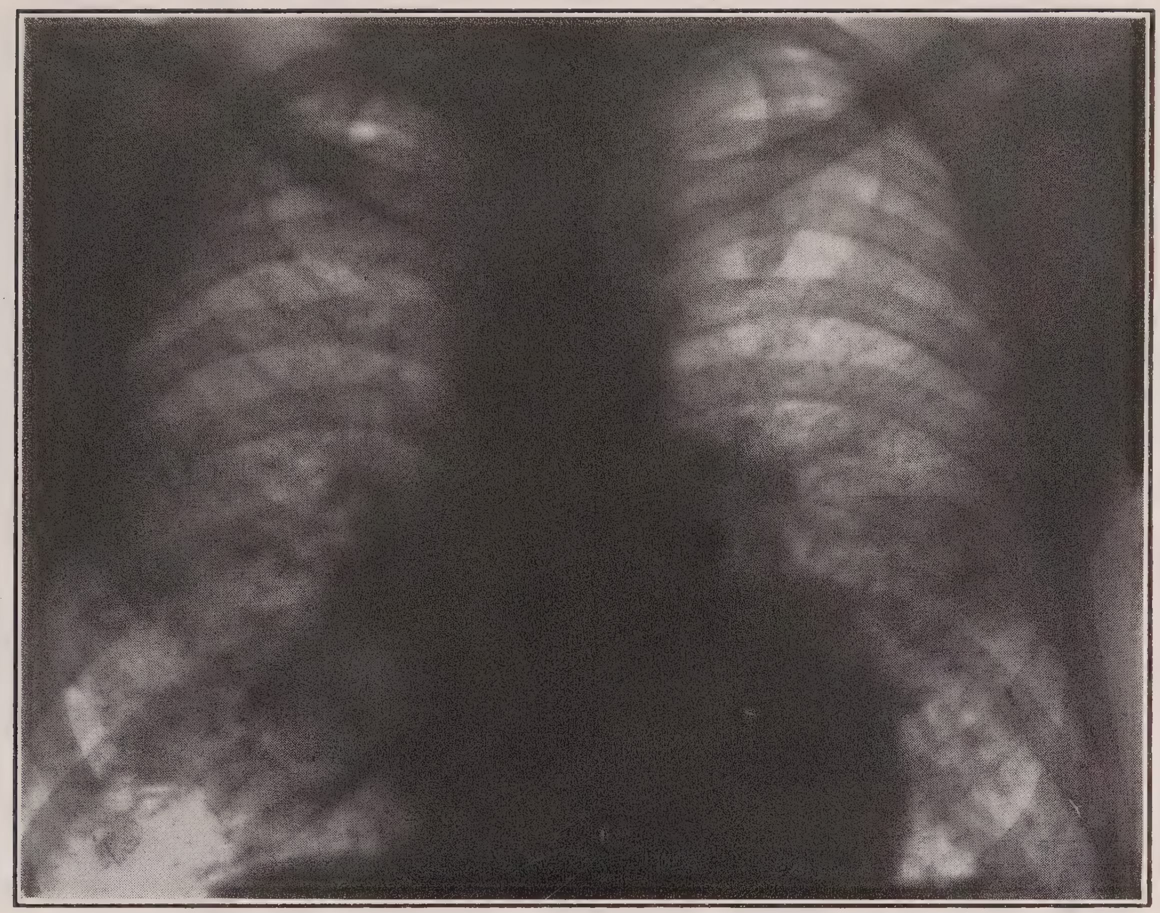


PLATE 7.—CASE C-584. SLAV. AGE 52.

Occupational History: Contract miner, 26 years; contract laborer, 7 years (14 years in gangway work, and 19 years at the breast). Had been a farmer in the old country before beginning to work in anthracite mining.

Estimated Dust Exposure: (*a*) Weighted average, 323 million particles per cubic foot. (*b*) Million particle years, 10,672.

Past Medical: Influenza, 1918.

Complaints: Pain in lower anterior chest, right side.

Physical Examination: Healthy, robust man, 65 inches tall and weighing 155 pounds. Chest expansion, 2 inches. Moderate clubbing of the fingers. Slight decrease of fremitus generally; slight general impairment of resonance, and moderate decrease in breath sounds. Slight dyspnea after the functional exercise test. Respiratory rate remained increased after 2-minute rest period following exercise, with prolonged expiration.

Fluoroscopy: Diaphragm irregular on the right; 2 plus limitation of diaphragmatic excursion, both sides. Hilus moderately increased in size and density.

Film: Note symmetrical distribution of increased densities, and marked emphysema.

Diagnosis: Anthraco-silicosis, well developed. Slight disability.

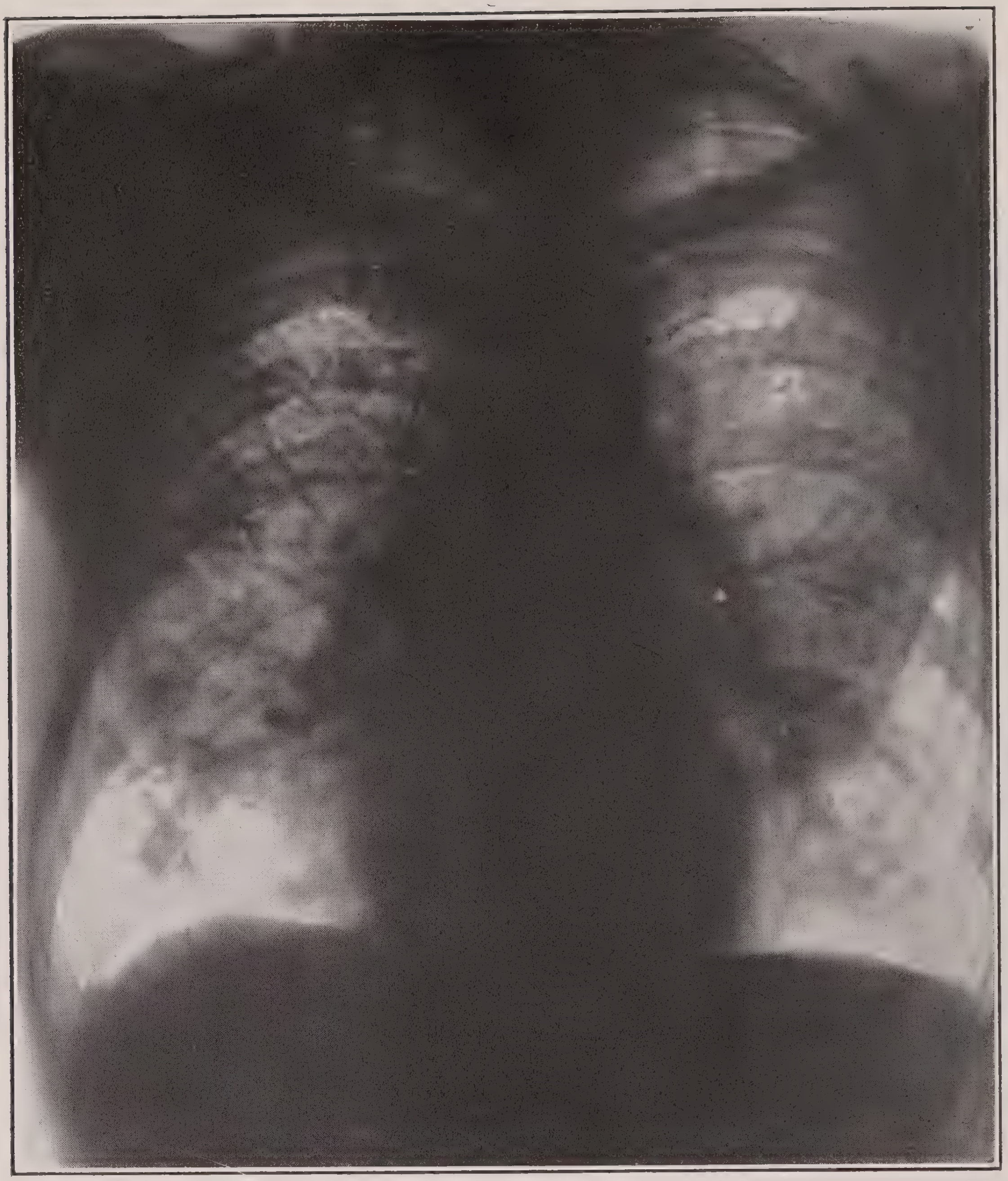


PLATE 8.—CASE C–158. AMERICAN, AGE 62.

Occupational History: Contract miner, 35½ years. Other occupations in anthracite chronologically from beginning of work at the mines: Slate picker, 1 year; mule driver (outside), 1 year; jig-tender in breaker, 3 years; loader under breaker and trackman, 4½ years; timberman (inside), 2½ years. Estimated idle time during occupational life, 6½ years.

Estimated Dust Exposure: (*a*) Weighted average, 194 million particles per cubic foot. (*b*) Million particle years, 9,188.

Past Medical: Subacute rheumatism, 1 month, 1918. Mine accident: Broke ribs and hurt stomach (3 months), 1930. Chronic pleurisy, past 3 years.

Complaints: Dyspnea and weakness since 1930. Pain in chest and region of the stomach. Heartburn for past 3 years. (Thought he was suffering from miners' asthma.)

Physical Examination: Comparatively healthy male, who had definitely lost weight. Height, 70 inches. Weight, 158 pounds (usual weight, 175 pounds). Chest was average or regular in shape. Chest expansion, 2 inches. Fremitus decreased generally. Resonance impaired at the bases posteriorly with hyper-resonance anteriorly. Breath sounds were decreased generally. Persistent subcrepitant and sibilant rales were heard in interscapula region and in right axilla. Dyspnea with prolongation of expiration after exercise.

Fluoroscopy: Diaphragm flat on left with moderate limitation of the diaphragmatic excursion. Hilar shadows moderately increased in size and density. Generalized fibrosis with coalescing mottled shadows, particularly in lower right lung field.

Film: Note increased hilar shadow and asymmetrical increase in density, both right and left lung fields; also emphysema at bases.

Diagnosis: Anthraco-silicosis with chronic pulmonary infection. Slight disability.

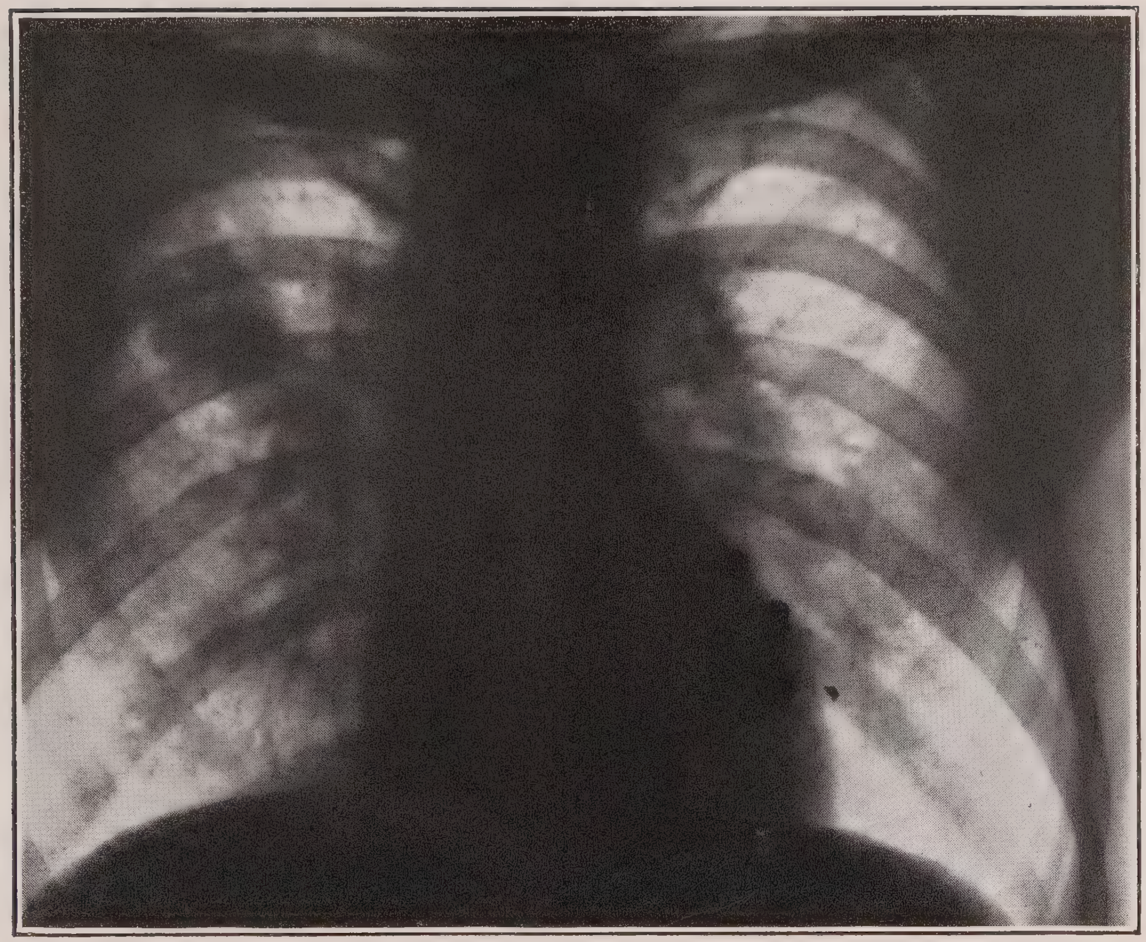


PLATE 9.—CASE C–80. POLE, AGE 48.

Occupational History: Contract miner, 21 years. Other occupations in anthracite chronologically from beginning of work at the mines: Buggy pusher, 1 year; contract laborer, 3 years.

Estimated Dust Exposure: (*a*) Weighted average, 307 million particles per cubic foot. (*b*) Million particle years, 7,712.

Past Medical: Influenza, 1919, 3 weeks' duration. Appendectomy, 1923. Strain of right shoulder, April 1933.

Complaints: Rheumatic pain in left shoulder.

Physical Examination: Healthy appearing man of medium development; height, 64 inches; weight, 130 pounds (usual weight, 143 pounds). Chest, asthenic type with moderate prominence of supra- and infra-clavicular fossae. Chest expansion, 3¼ inches. Fremitus was increased over right lung from level of sixth thoracic vertebra and fourth rib up. Breath sounds moderately distant. No rales. Slight dyspnea after functional exercise test. Expiration prolonged. No clubbing of the fingers.

Fluoroscopy: Slight limitation of diaphragmatic excursion on the left. Hilar shadows increased slightly in size and density. Marked generalized fibrosis, right mid-lung field.

Film: Note hilar shadows increased slightly in size and density. Lung fields show second degree diffuse grainy appearance with conglomerate shadow in right mid-lung field. Emphysema at bases.

Comment: The location of the conglomerate shadow suggests that it may have originated from a healed Ghon's focus.

Diagnosis: Anthraco-silicosis. Latent infection. No disability.

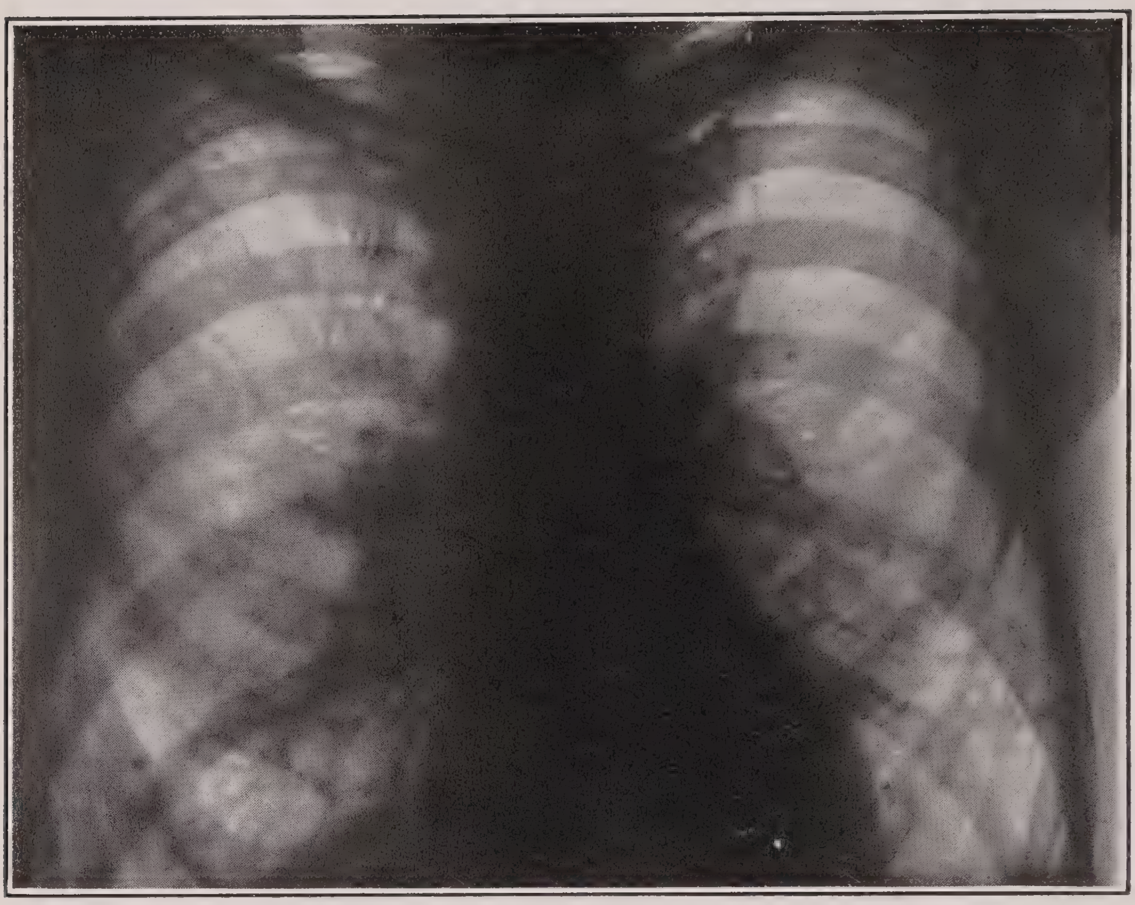


PLATE 10.—CASE A-346. LITHUANIAN, AGE 60.

Occupational History: Mine laborer (contract), 3 years; contract miner, 35 years. All work at breast in dry mine.

Estimated Dust Exposure: (*a*) Weighted average, 480 million particles per cubic foot. (*b*) Million particle years, 19,200.

Past Medical: Was told that he had consumption in 1918.

Complaints: Productive morning cough and shortness of breath, especially in the morning. Has been weak and unable to do hard manual labor since about 1918.

Physical Examination: Emaciated, but says he has not lost any weight the past 10 years. Has a lesion on the lower lip which from history and appearance would judge to be carcinomatous. Barrel chest with but one-half inch chest expansion. Definitely dyspneic; pulse and respiration remained high after rest, although he was not able to complete the exercise test. Expiration prolonged. Decreased fremitus, and percussion note hyperresonant at both bases. Persistent sibilant and sonorous rales at both bases.

Fluoroscopy: Diaphragm movement practically fixed, with some irregularities at the right costo-phrenic sinus. Increased density of hilar shadow.

Film: Note the general distribution of emphysema, thickened interlobar pleura on the right. Scattered shadows at right base and along hilum, with the appearance of calcified nodules. The film shows an area at the right base which does not reproduce well, but has almost the appearance of a cystic condition.

Diagnosis: Anthraco-silicosis, with moderate to marked disability, to which age and infection contribute as well as anthraco-silicosis. (Carcinoma of the lip.)

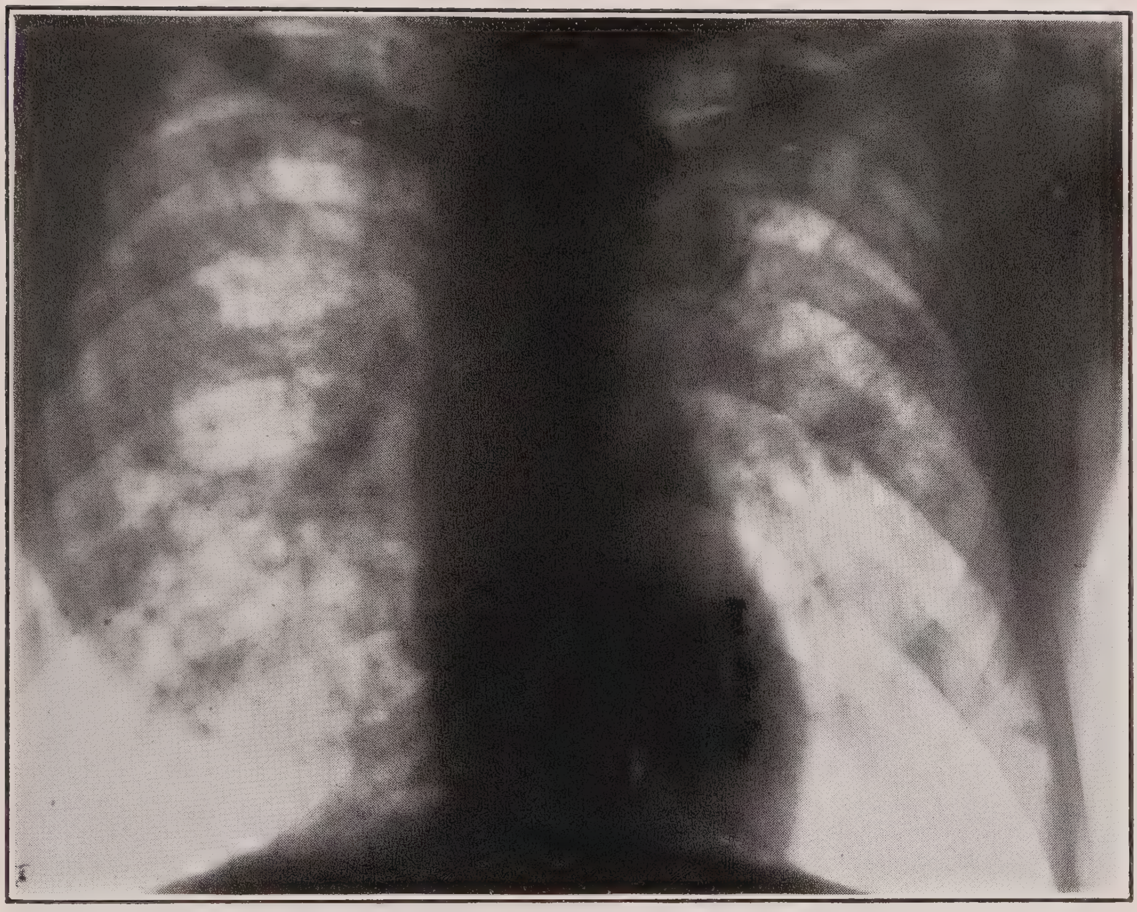


PLATE 11.—CASE C-117. POLE, AGE 53.

Occupational History: Contract miner (gangway), 10 years; contract miner (breast and pillar work), 13 years. Prior to this, contract laborer 2 years, and company loader 4 years. Before entering the anthracite industry had worked in shoe shop in old country 3 years. Estimated time idle, 5 years.

Estimated Dust Exposure: (*a*) Weighted average, 263 million particles per cubic foot. (*b*) Million particle years, 7,622.

Past Medical: Denied ever being severely ill.

Complaints: None.

Physical Examination: Comparatively healthy male. Height, 66 inches; weight, 145 pounds (usual). Average shaped chest with retraction of the apices. Chest expansion, 1¾ inches. Fremitus decreased generally. Resonance markedly impaired over upper third of each lung. Breath sounds generally decreased. Sibilant and sonorous rales heard throughout, and were persistent after cough. No clubbing of the fingers. B. P. 170/104. Pulse rate before, immediately after, and 2 minutes after functional exercise test, respectively: 108, 156, and 108. Respiratory rate, 18, 28, and 22. Expiration was prolonged.

Fluoroscopy: Moderate limitation of diaphragmatic excursion, both sides. Hilar shadows moderately increased in size and density. Coalescing nodular shadows upper two-thirds of each lung field.

Film: Note slight irregularity of the right diaphragm. The size of the hilar shadow is indefinite, but increased slightly in density. Coarse, coalescing, reticular shadows are seen in upper two-thirds of each lung field. These shadows more dense in lateral periphery and apices. There are scattered areas suggestive of bronchiectasis. Moderate emphysema of the bases.

Diagnosis: Anthraco-silicosis with infection. Slight disability.

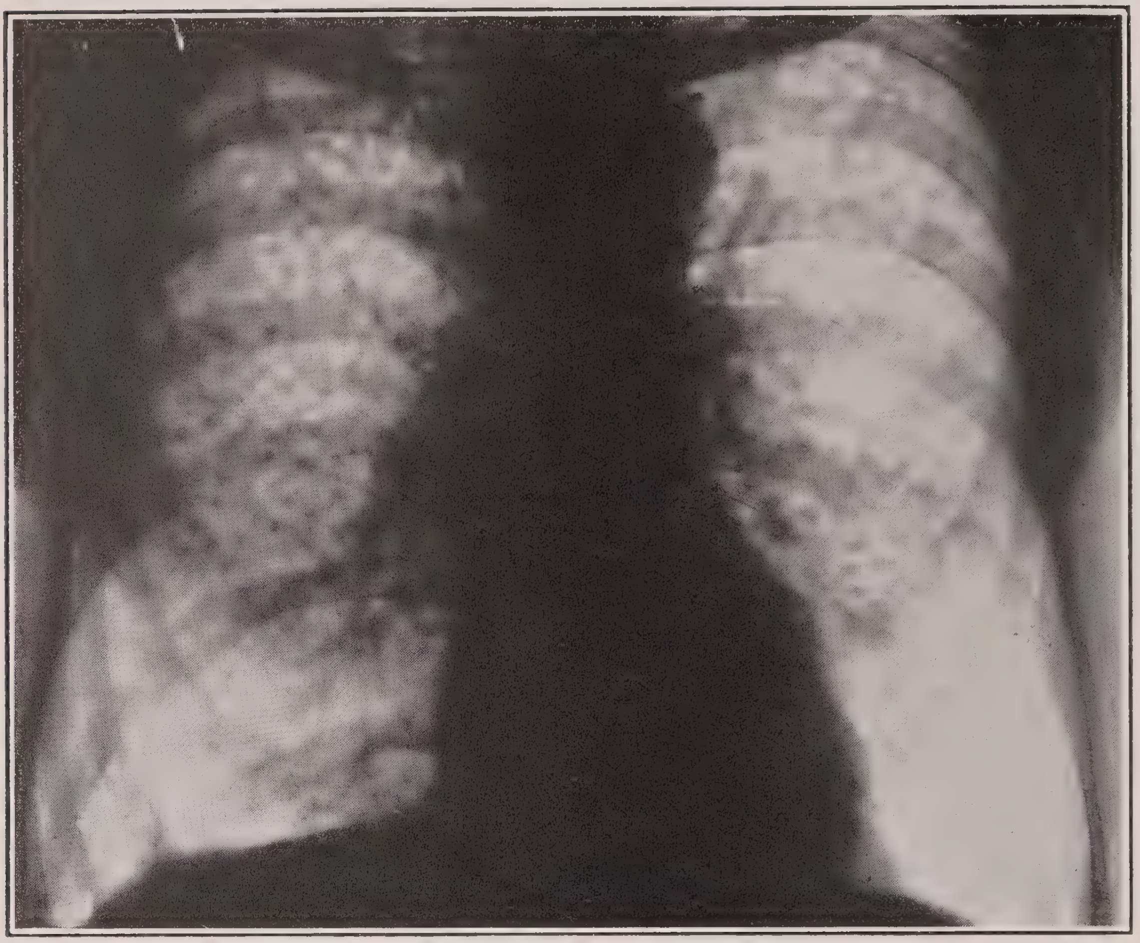


PLATE 12.—CASE C-92. AMERICAN. AGE 65.

Occupational History: Contract and company miner, 38 years; company laborer, 5 years previously. Occupations other than in anthracite: Huckster, 3 years; bakery helper, 6 years; florist's helper, 2 years. Estimated time idle, 4 years.

Estimated Dust Exposure: (*a*) Weighted average, 279 million particles per cubic foot. (*b*) Million particle years, 11,987.

Past Medical: Had two butties who had miner's asthma; the first died of the disease. One daughter died of tuberculous meningitis in 1924. Had pneumonia in 1903. Frequent colds and bronchitis.

Complaints: Productive cough (mucopurulent and black) since 1913. Dyspnea and pain in chest since 1923. Appetite poor past 2 years.

Physical Examination: Underweight, senile man. Height, 66 inches; weight, 158 pounds (usually 195). Chest flat with retraction of the apices. Chest expansion, 1.5 inches. Fremitus decreased generally. Resonance impaired over upper fronts and apices and bases posteriorly; hyperresonance over bases anteriorly and in axillae. Persistent crepitant rales. Dyspnea after exercise. Expiration prolonged.

Fluoroscopy: Diaphragm fixed. Generalized fibrosis with mottling.

Film: Note pleural diaphragmatic adhesion on right. Emphysema at bases and left upper. Density more marked on right, including apex. Shadows less discrete, of a mottled character. A few of the shadows resemble those cast by pulmonary calcifications.

Diagnosis: Anthraco-silicosis. Clinical pulmonary tuberculosis; slight disability.

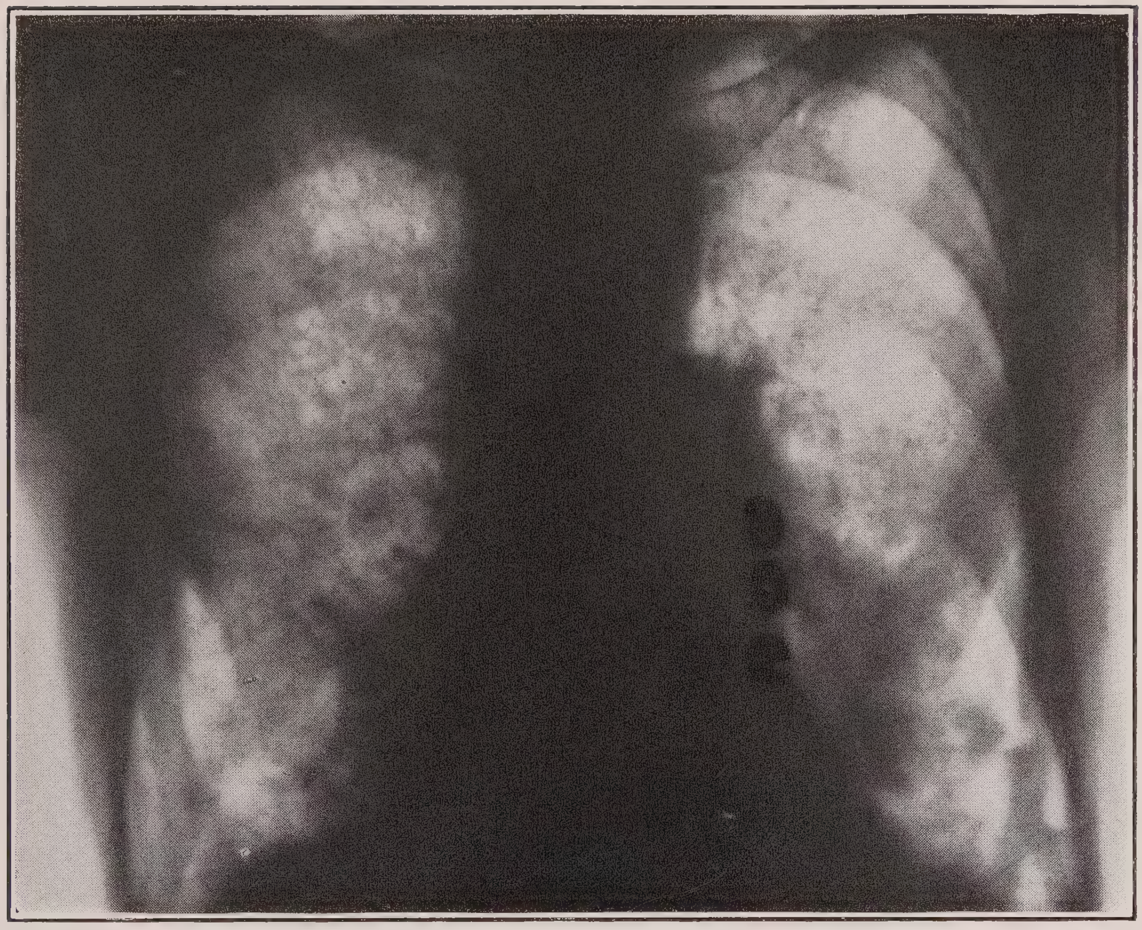


PLATE 13.—CASE A–603. AMERICAN, AGE 56.

Occupational History: Slate picker (anthracite), 2 years. Shaftman's helper, 3 years on surface. Shaft tender, surface, 2 years. Spragger (outside), 2 years. Retail coal loader under breaker, 2 years; car loader under breaker, 2 years. Carpenter's helper, underground, 5 years. Bratticeman and carpenter, underground, 22 years.

Estimated Dust Exposure: (*a*) Weighted average 30 million particles per cubic foot. (*b*) Million particle years 1,293.

Past Medical: Severe bronchitis each year since 1930.

Complaints: Marked productive cough, and shortness of breath past 10 years. Has been losing weight past 2 years. Constant chest pain; poor appetite.

Physical Examination: Chronically ill, emaciated male. Marked dyspnea upon exertion. Exercise test not completed. Expiration prolonged. Clubbing of fingers. Hypotension. Barrel chest. Expansion, 1½ inches. Decreased fremitus and impaired resonance generally. Breath sounds harsh. Persistent crepitant rales above fourth rib posteriorly right and left.

Fluoroscopy: Diaphragm fixed and irregular. Partial obliteration from costophrenic sinus on both sides. Increased density generally, more marked on right.

Film: Note grainy appearance of the shadows, position and type of heart. Apical density bilateral; tendency to peripheral density more marked on the right. Emphysema more marked upper left.

Diagnosis: Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Marked disability.

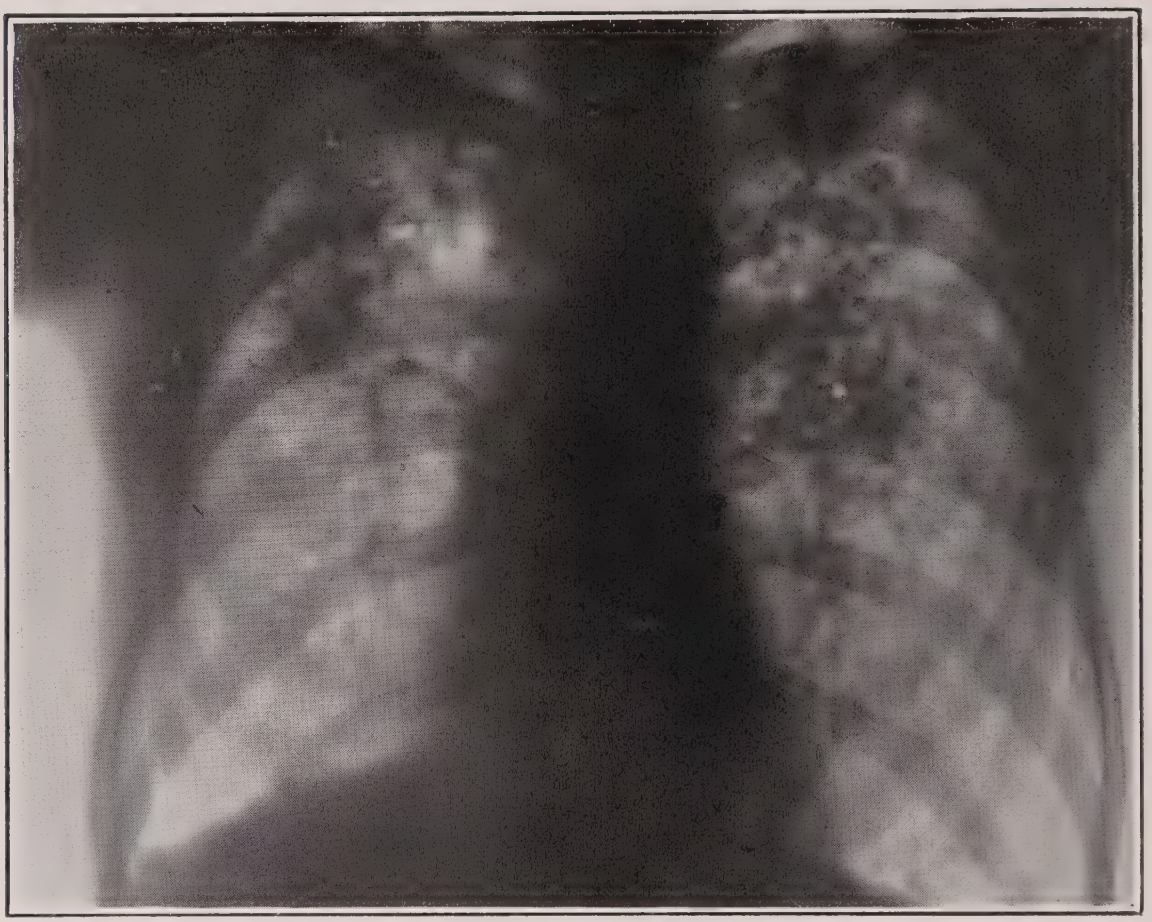


PLATE 14.—CASE A-1026. AMERICAN. AGE 49.

Occupational History: Rope rider (slopeman) anthracite, 5 years; car runner, 5 years; mule driver, 20 years; slate picker, 6 years. Estimated time idle, 2 years.

Estimated Dust Exposure: (*a*) Weighted average, 122 million particles per cubic foot. (*b*) Million particle years, 4,410.

Past Medical: (One member of household has had chronic tuberculosis since 1920). History of severe attacks of influenza, 1919—in bed 1 month. Cerebral concussion in 1932. Osteomyelitis first rib and right clavicle in 1915.

Complaints: Loss of weight, and weakness. No appetite past year. Very short of breath upon exertion.

Physical Examination: Chronically ill individual; emaciated; asthenic type chest; retracted apices. Chest expansion 1½ inches. Persistent crepitant rales, both uppers. Began exercise test but was unable to complete it. Hypotension.

Fluoroscopy: Diaphragm practically fixed, irregular on the right; drop type heart shadow; marked increase in density, upper one-half both lung fields.

Film: Note emphysema both bases, and dense irregular shadows both uppers, some having the appearance of those cast by calcified masses.

Diagnosis: Early anthraco-silicosis. Clinical pulmonary tuberculosis. Marked disability.

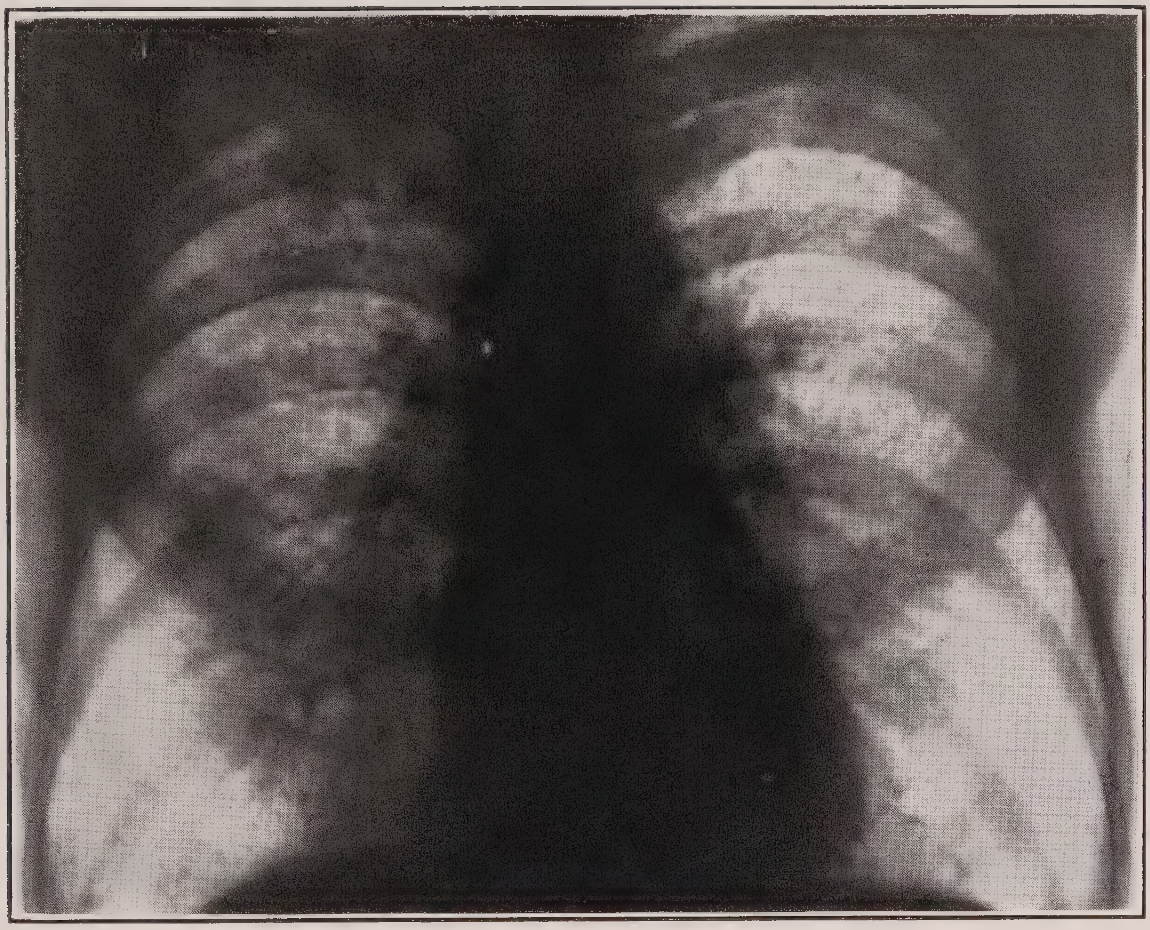


PLATE 15.—CASE A–449. AMERICAN, AGE 60.

Occupational History: Tending door, and running cars, 5 years. Anthracite mine laborer, 5 years. Anthracite contract miner, 34 years; estimated time idle, 3 years. All work underground at the face. Negligible time spent at rock work.

Estimated Dust Exposure: (*a*) Weighted average, 436 million particles per cubic foot. (*b*) Million particle years, 20,515.

Past Medical: One or two disabling colds per year for past 6 years. Rheumatism, not bedfast, 1924.

Physical Examination: Well developed male, weight 131–141 three years ago. Chest expansion, 2 inches. Pulse and respiratory rate returned to normal range after exercise. Expiration slightly prolonged. Breath sounds harsh, no rales. Slight general decrease in fremitus.

Fluoroscopy: Decreased diaphragmatic motion right and left. Hilar shadows increased in size and density. Increased density of right upper lung field, including right apex.

Film: Note emphysema at the bases and left upper lung field, and circumscribed area of density right infra-clavicular region, and general increase in density right upper two-thirds of lung fields.

Diagnosis: Anthraco-silicosis, with no disability. Latent pulmonary infection.

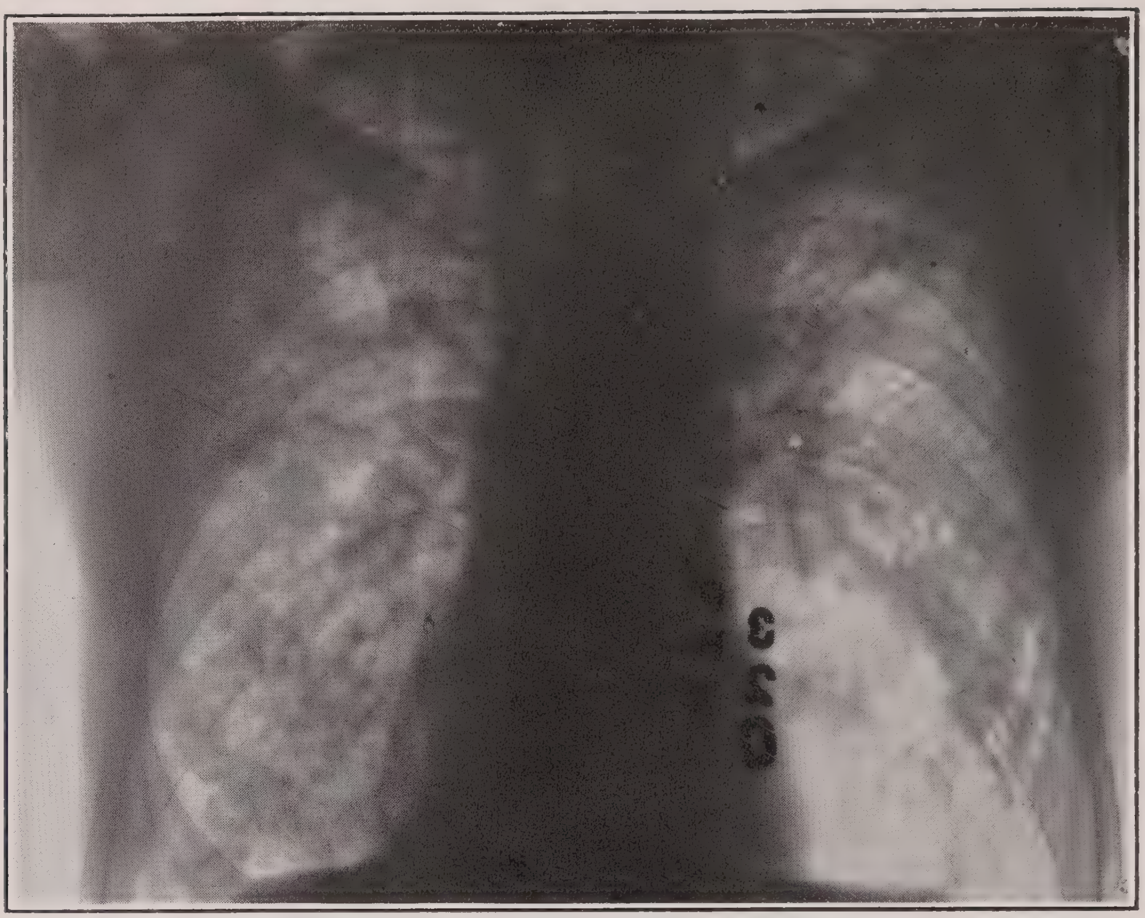


PLATE 16.—CASE C-320. AUSTRIAN, AGE 53.

Occupational History: Contract miner, 24 years. Other occupations in anthracite, from beginning of work at the mines: Contract laborer, 2 years. Farmer in old country, 8 years. Estimated time idle, 4 years.

Estimated Dust Exposure: (*a*) Weighted average, 328 million particles per cubic foot. (*b*) Million particle years, 8,528.

Complaints: Morning productive cough since 1930. Appetite poor past 2 years. Dyspnea since 1928.

Physical Examination: Slender, emaciated man. Weight, 140 pounds, and height, 67 inches. Flat type chest with retraction of the apices and prominent fossae. Chest expansion 1½ inches. No clubbing of fingers. Fremitus moderately decreased generally. Percussion note hyperresonant over lower anteriors, and markedly impaired over remaining lung area. Breath sounds decreased generally. Friction sounds at both bases posteriorly. Persistent sonorous, sibilant and subcrepitant rales present throughout. Expiration prolonged. B. P. 118/90. Pulse weak. Dyspnea marked after exercise.

Fluoroscopy: Diaphragm fixed. Hilar shadows moderately increased in size and density. Drop type heart. Generalized fibrosis 3 plus, with coalescence of nodular shadows in both uppers.

Film: Note evidence of mediastinal traction. Emphysema at the right base, "mottled" appearance of the shadows.

Diagnosis: Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Moderate disability.

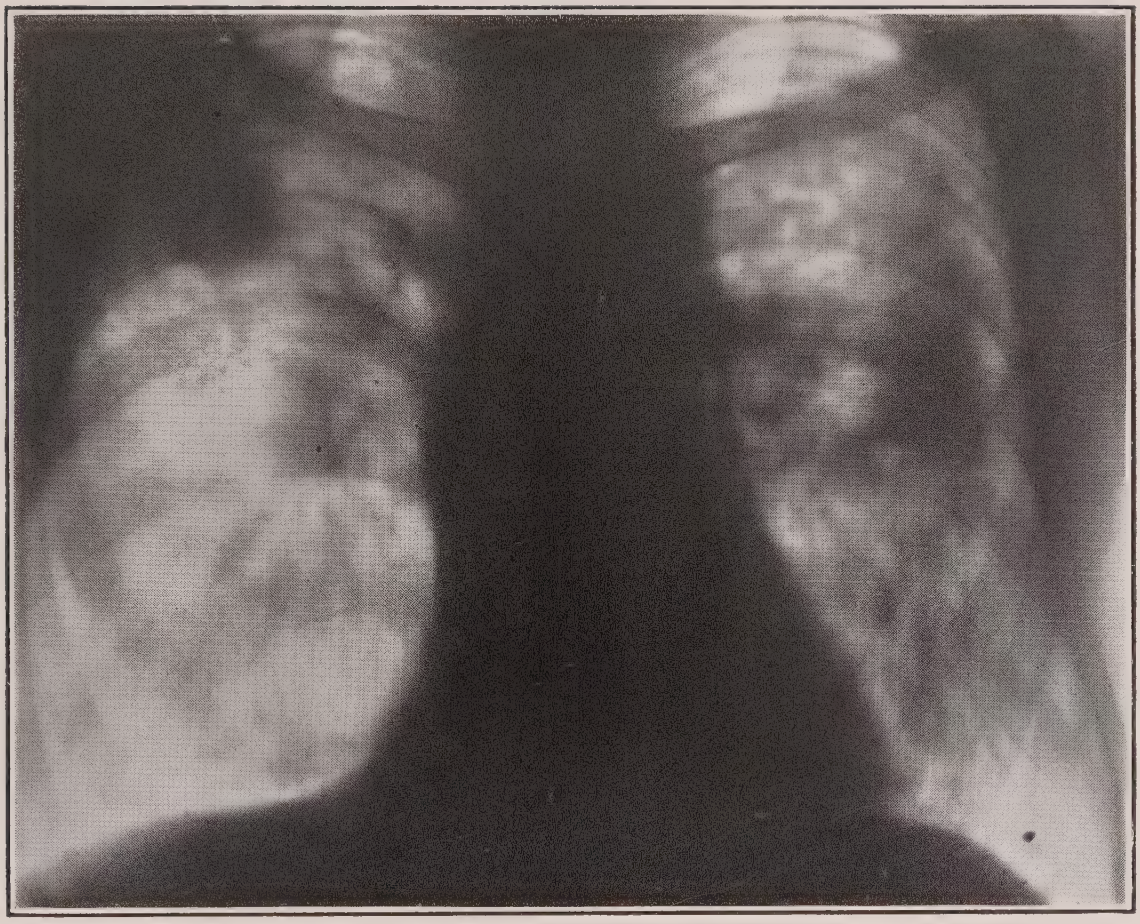


PLATE 17.—CASE A-1081. LITHUANIAN, AGE 62.

Occupational History: Lived on farm in Lithuania until 18 years of age. Worked as shoemaker's apprentice, 3 years. Came to United States at the age of 21. Mine laborer, 1 year. Anthracite contract miner, 37 years. Doorman past 3 years. Over 30 years of mine work in gangway, one-third of time loading and drilling rock.

Estimated Dust Exposure: (*a*) Weighted average, 440 million particles per cubic foot. (*b*) Million particle years, 18,022.

Past Medical: Many colds, but none disabling. Fractured right leg in 1909 in mine accident.

Complaints: Persistent, unproductive cough; but occasional slight blood streaks in sputum. Very short of breath, and so weak had to quit active mining. Appetite poor for past 3 years.

Physical Examination: Emaciated, chronically ill man; unable to do exercise test. Barrel chest. Expansion 2½ inches. Breath sounds harsh. Impaired fremitus and percussion note general. Persistent crepitant rales over upper fronts and posterior. Expiration prolonged.

Fluoroscopy: Diaphragm practically fixed. Hilar shadow enlarged. Upper right and upper two-thirds of the left lung fields show increased density.

Film: Note marked evidence of emphysema, and asymmetrical distribution of pulmonary densities.

Diagnosis: Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Marked disability.

PLATE 18.—CASE B-462. POLE, AGE 43.

Occupational History: Company miner, 1 year. Contract miner, 9 years. Company miner, 3 years. Mule driver, 1 year. Company and contract labor, 4 years. Outside labor, anthracite, ½ year. Picked slate (dry breaker), 1 year. Estimated time idle, 5½ years. (All work at one anthracite mine. Most of the company mining in rock and tunnel work. Part of contract mining in chute work, considerable rock. Classed as rock man.)

Estimated Dust Exposure: (*a*) Weighted average, 147 million particles per cubic foot. (*b*) Million particle years, 2,828.

Past Medical: Pneumonia, 1924. Rheumatism, 6 weeks in hospital, 1912.

Complaints: Shortness of breath since 1930. Constant dry cough; loss of more than 20 pounds in weight. Weak. Appetite poor.

Physical Examination: Emaciated, chronically ill individual. Dyspnea marked after exercise. Respiratory rate remained high with prolonged expiration. Asthenic type chest with retracted apices. Chest expansion, 3 inches. Breath sounds harsh. Persistent crepitant rales over upper two-thirds, more so on right.

Fluoroscopy: Diaphragmatic motion limited on right and left. Increased density of hilar shadow, which is rather indefinite in outline. Cardiac enlargement to the right. Increased density upper two-thirds with conglomerate mass toward periphery, right upper lung field.

Film: Note marked emphysema at the bases, cardiac enlargement, and asymmetrical distribution of pulmonary densities.

Diagnosis: Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Slight disability.

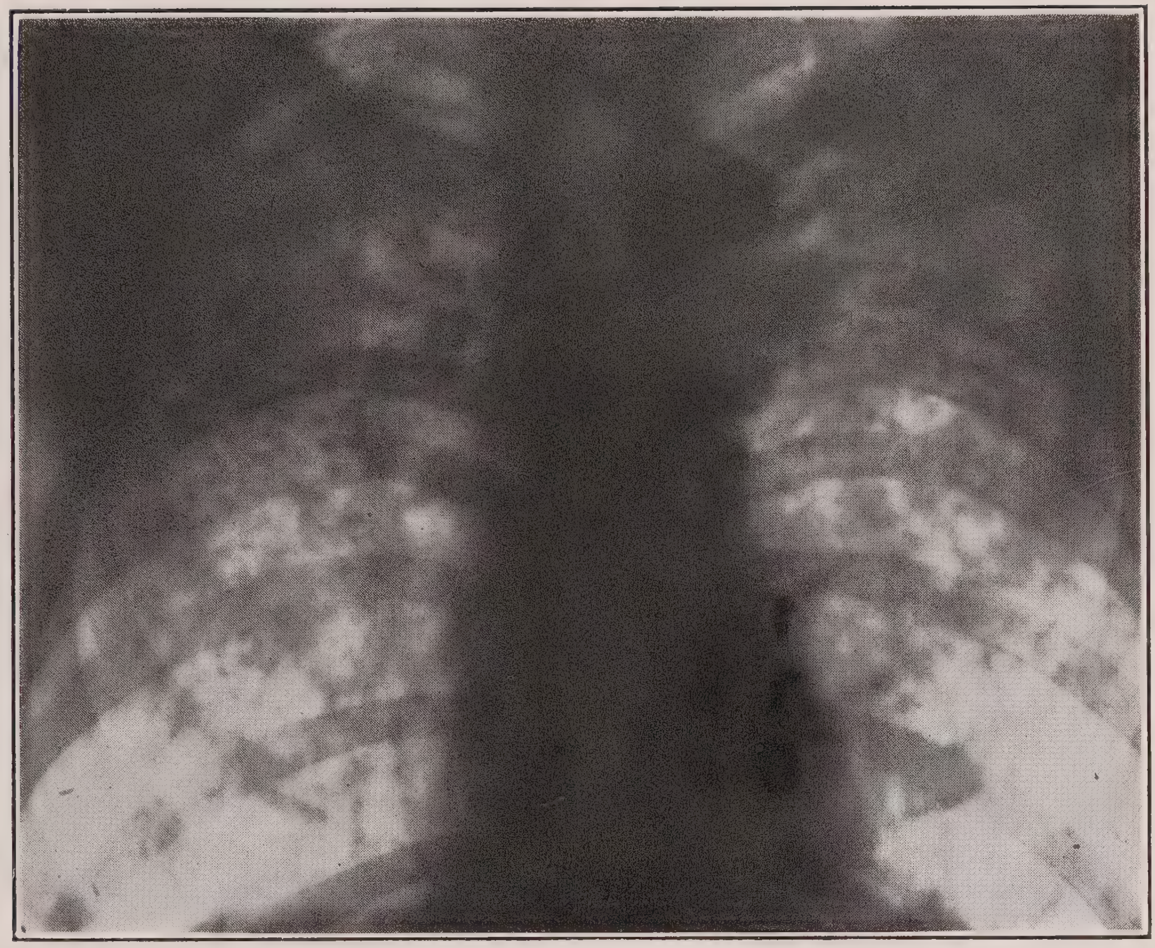


PLATE 19.—CASE B-170. POLE, AGE 46.

Occupational History: Contract miner, 15 years. Other occupations chronologically from beginning of work: Slate picker, 1½ years; delivery man (furniture), 6½ years; mine laborer (anthracite), 1 year; machine runner's helper on rock (anthracite), 1 year; machine runner and chargeman (anthracite), 3 years.

Estimated Dust Exposure: (*a*) Weighted average, 197 million particles per cubic foot. (*b*) Million particle years, 4,222.

Past Medical: Influenza, 1 week, June 1933.

Complaints: Productive cough (black, mucopurulent sputum); moderate dyspnea with difficult expiration; anorexia, 9 months; pain in upper abdomen on coughing; dizziness and pain in lower limbs.

Physical Examination: Emaciated, chronically ill man. Height, 63 inches; weight, 128 pounds (weight last year, 140 pounds). Chest flat, phthisical in type, with moderate prominence of the supra- and infra-clavicular fossae; expansion, 2 inches with flaring of the lower ribs. Fremitus increased over upper portions of each lung. Resonance impaired over the lower anterior pulmonic areas, and dull from the third rib and eighth thoracic vertebra up R & L. Breath sounds were bronchovesicular over the dull areas, and distant over the impaired areas. Subcrepitant and crepitant rales over dull areas, and these persisted after cough. Hypotension. Pulse 100 before exercise, and afterward, 152; after rest, 112. Respiratory rate remained high; prolonged expiration.

Fluoroscopy: Diaphragm almost fixed, although round in contour. Infiltration near periphery upper one-half each lung field extending into apices. Medium sized nodular densities mid lung fields, and emphysema at bases. Generalized fibrosis 2 plus with infection.

Film: Note marked emphysema at bases; also linear shadows extending to diaphragm from dense areas above. Right apex and peripheral upper one-third more dense than left.

Diagnosis: Late anthraco-silicosis with clinical pulmonary tuberculosis. Moderate disability.

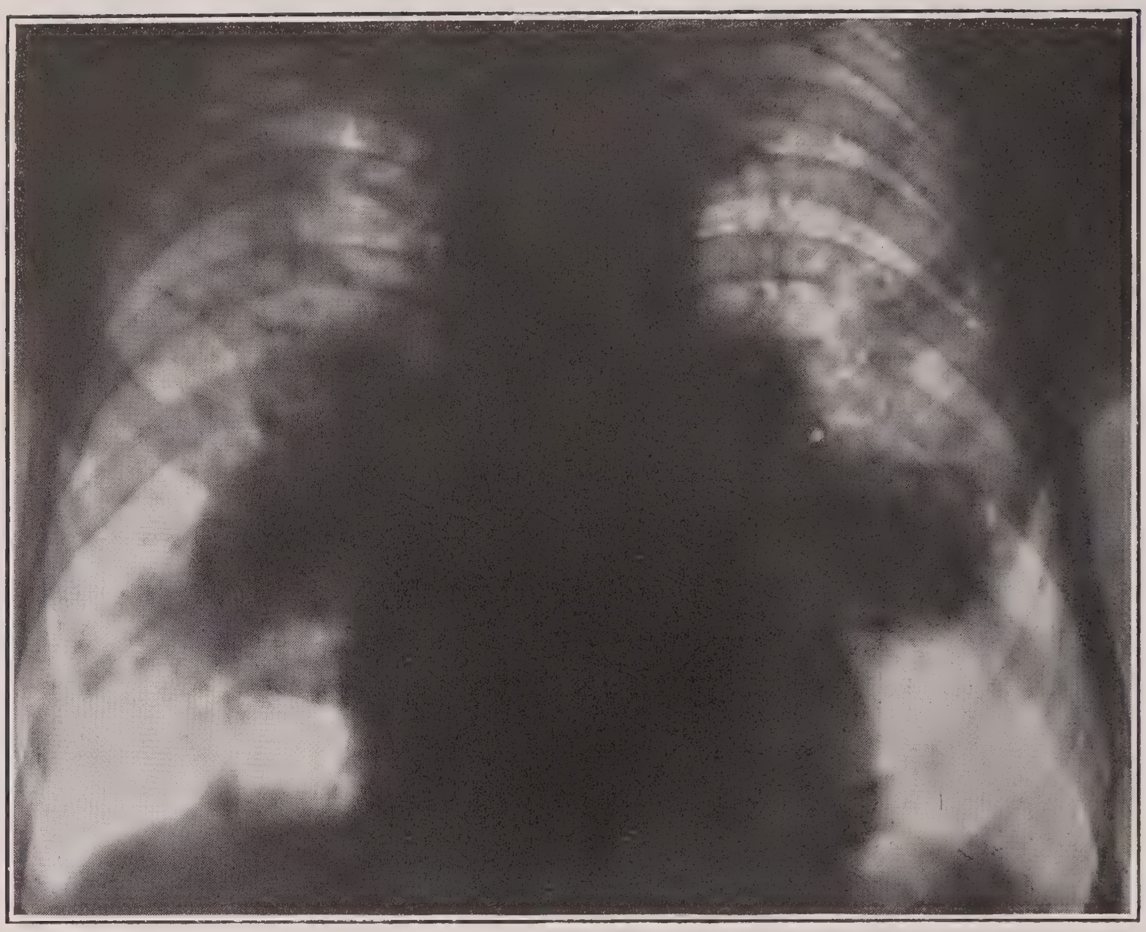


PLATE 20.—CASE A-308. LITHUANIAN, AGE 60.

Occupational History: Farmer in old country until 20 years of age; then came to United States. Spent 20 years as mine laborer in anthracite, and for past 20 years has been a contract miner. Estimated idle time, 5 years.

Estimated Dust Exposure: (*a*) Weighted average, 480 million particles per cubic foot. (*b*) Million particle years, 19,200.

Past Medical: Pneumonia at the age of 12; influenza in 1929; chronic bronchitis since 1930.

Complaints: Productive cough and shortness of breath, gradually increasing since 1930. Feels weak. (Butty does his hard work).

Physical Examination: Emaciated, chronically ill man. Dyspnea evident without exercise. Unable to complete test. Expiration prolonged. Flat chest, retracted apices; expansion ¾ inch. Impaired fremitus and percussion throughout. Friction rub at right base. Persistent rales throughout, crepitant and subcrepitant in type. Pulse at rest 104. Respiration 30.

Fluoroscopy: Fixed irregular diaphragm. Right and left, conglomerate shadows continuous with the hilus. Increased density upper two-thirds both lung fields, more so on right.

Film: Note marked emphysema at both bases, irregularities of the diaphragm, and beginning conglomerate shadow right subclavicular region toward periphery.

Diagnosis: Advanced anthraco-silicosis; clinical pulmonary tuberculosis; moderate disability.

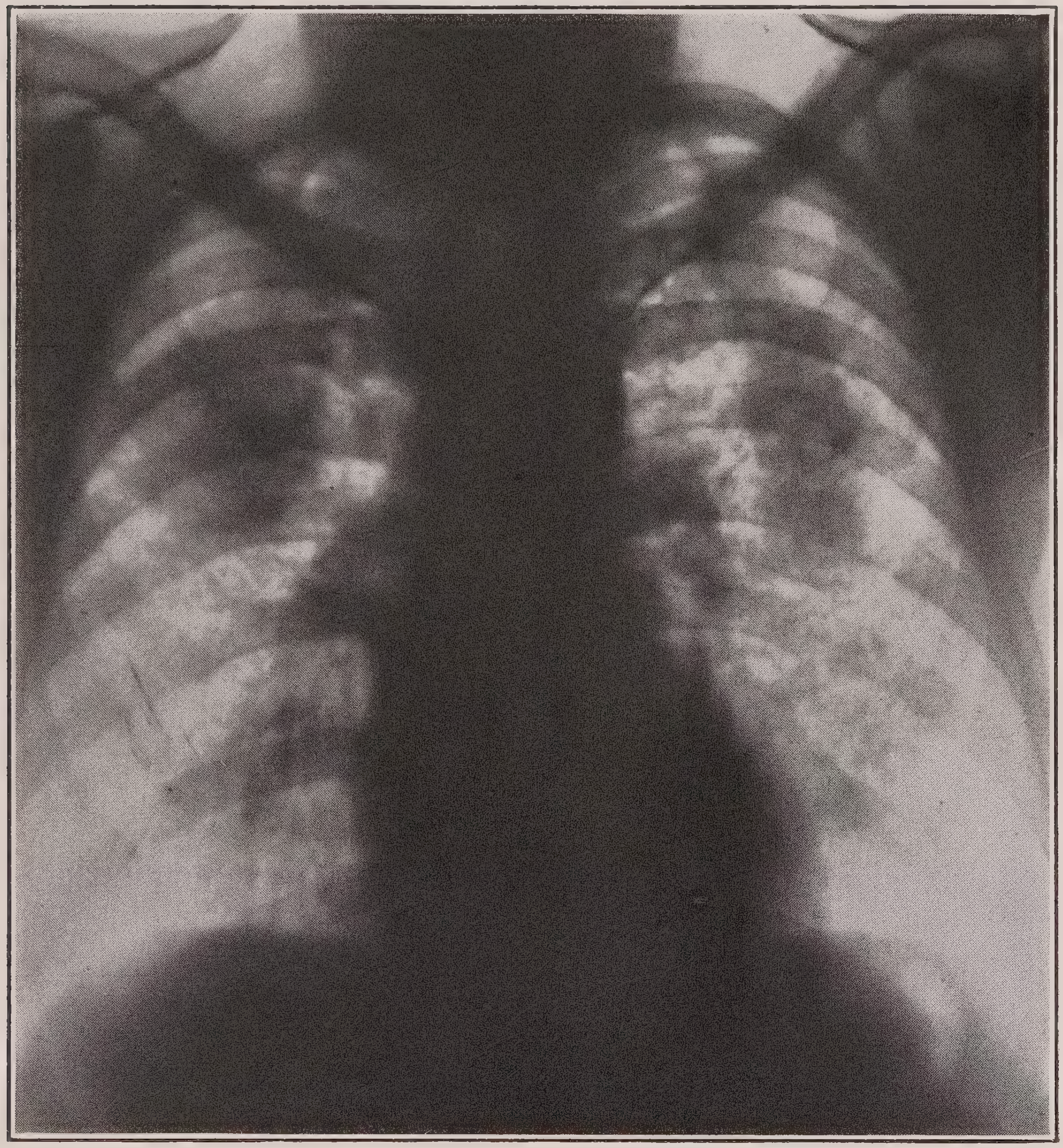


PLATE 21.—CASE C-657. ENGLISH, AGE 62.

Occupational History: Contract miner, 41 years (one-half time in gangway). Other occupations in anthracite, chronologically from beginning of work at mines: Slate picker, 7 years; contract laborer, 6 years; worked at no other trade.

Estimated Dust Exposure: (*a*) Weighted average, 288 million particles per cubic foot. (*b*) Million particle years, 15,537.

Past Medical: His father died of miners' asthma. He had pneumonia, 2 weeks' duration, 1913, and was subject to frequent colds which caused him to remain off work on the average of 5 days per year.

Complaints: Labored breathing and shortness of breath began in 1924, and has become progressively worse.

Physical Examination: Comparatively healthy man. Height, 70 inches; weight, 190 pounds (usual weight). Chest slightly barrel shaped; expansion 1¼ inches. Fremitus was decreased generally. Some impairment to percussion at the bases, but no definite hyperresonant areas. No rales. Slight dyspnea present after the functional test, and the respiratory rate remained increased (30) after 2-minute rest period.

Fluoroscopy: Diaphragmatic excursion excellent. Heart appeared slightly enlarged. Hilar shadows were moderately increased in size and density. Both lung fields showed a moderate degree of generalized fibrosis with coalescing conglomerate shadows in both upper thirds.

Film: Note regular appearance of diaphragm. Marked emphysema at bases, and beginning conglomerate shadows in both uppers.

Diagnosis: Late anthraco-silicosis. Slight disability.

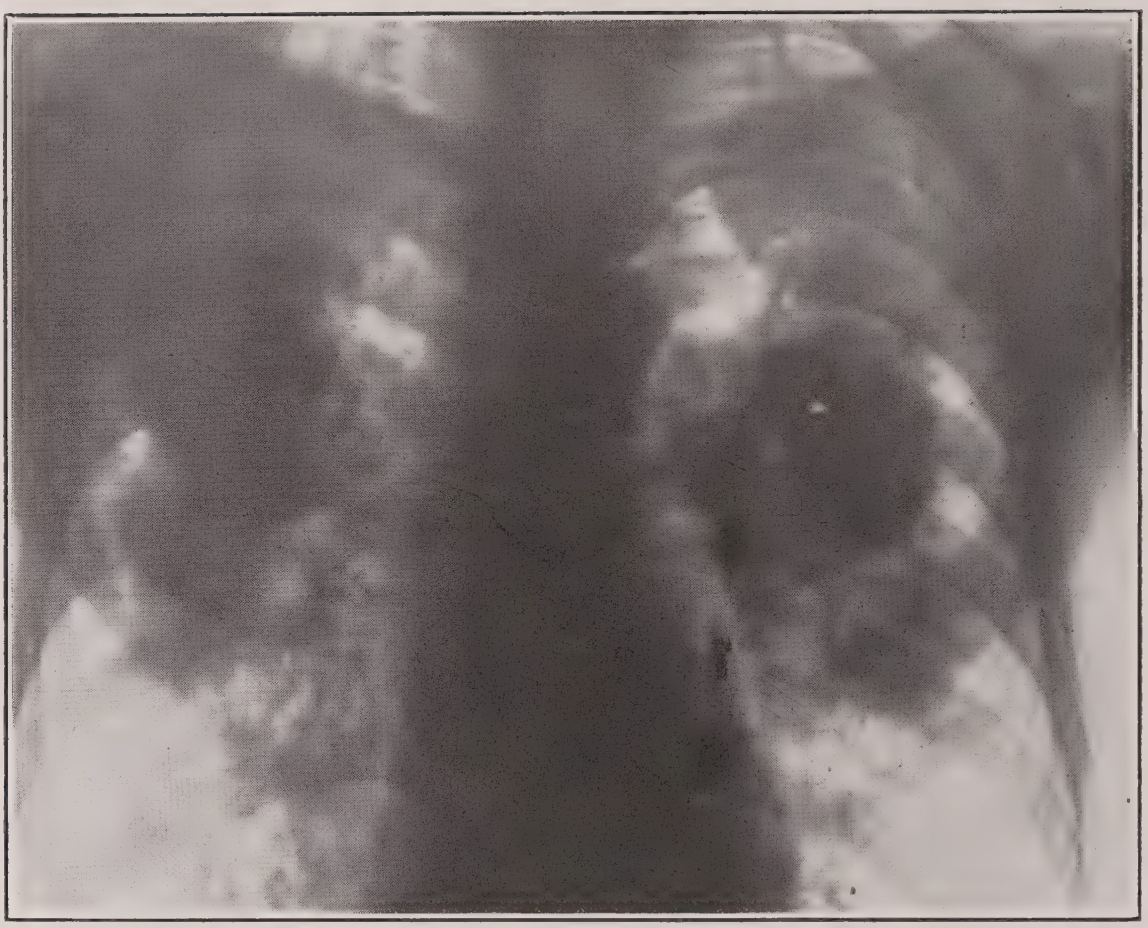


PLATE 22.—CASE A-916. AMERICAN, COLORED, AGE 50.

Occupational History: (39 years dry breaker). Slate picker, 7 years. Sweeper, 7 years. Footman, 11 years; oiler, 10 years; engineer, 4 years.

Estimated Dust Exposure: (*a*) Weighted average, 238 million particles per cubic foot. (*b*) Million particle years, 9,300.

Past Medical: Pneumonia and pleurisy, 1931; rheumatism 1930–31, 18 months.

Complaints: Productive cough; occasional night sweats. Loss of 20 pounds in weight over the past 3 years.

Physical Examination: Fairly healthy appearing individual; slender type. Asthenic type chest; hypotension. Prominent supra- and infra-clavicular fossae, 2 plus clubbing of fingers. Chest expansion, 2¼ inches. Fremitus and percussion note impaired generally. Breath sounds harsh; persistent subcrepitant rales at the right base. Expiration prolonged after exercise, and moderate dyspnea.

Fluoroscopy: Diaphragm nearly fixed and flat. Marked increase in density of lung field above level of lower pole of hilars, right and left. Conglomerate shadows extending to periphery on the right.

Film: Note marked emphysema at the bases, and massive conglomerate shadows in both upper two-thirds. Diaphragm not shown, loss of linear markings; apices fairly clear; vertical type heart.

Diagnosis: Advanced anthraco-silicosis. Chronic pulmonary infection. Moderate disability.

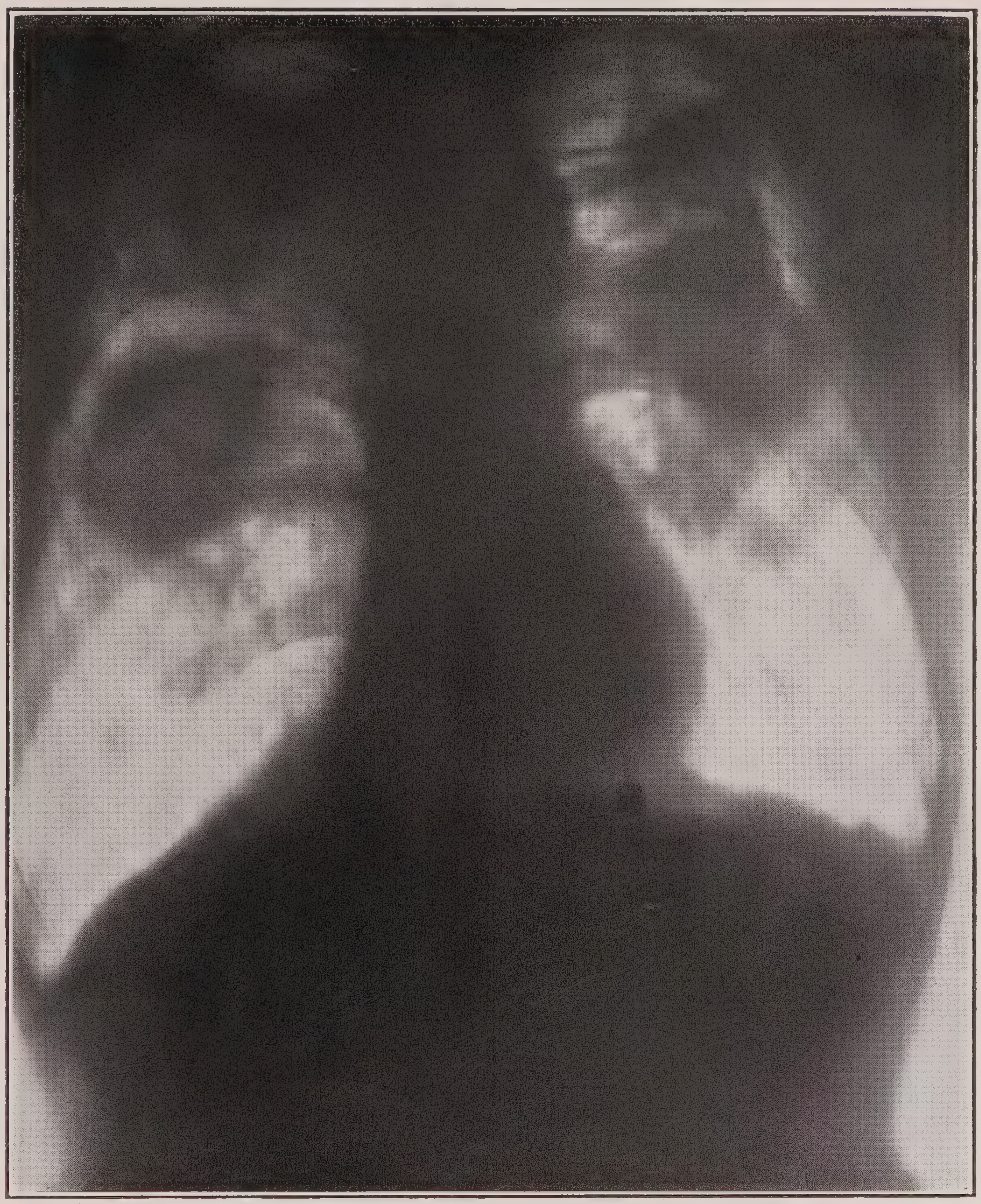


PLATE 23.—CASE C–518. AMERICAN, AGE 51.

Occupational History: Contract miner, 28 years (breast 4 years, gangway 24 years). Other occupations in anthracite, chronologically from beginning of work at the mines: Slate picker, 2 years; door tender, ½ year; mule driver, 2 years, and company laborer, 3 years. Most of the time a rock worker.

Estimated Dust Exposure: (*a*) Weighted average, 334 million particles per cubic foot. (*b*) Million particle years, 11,852.

Past Medical: Influenza, 1918 (2 weeks). Frequent colds and bronchitis since 1928; pleurisy in 1932.

Complaints: Moderate and increasing dyspnea since 1927; slightly productive cough.

Physical Examination: Asthenic male. Height, 71 inches; weight, 157 pounds (weight 1 year ago, 165). Barrel-shaped chest with retraction of the apices. Chest expansion, 2 inches. Fremitus generally decreased. Resonance impaired over the apices and upper two-thirds of each lung, with hyperresonance in the lower axillae. Breath sounds decreased. Occasional sibilant rale heard in the bases. Moderate degree of dyspnea present after the functional exercise. Expiration prolonged after exercise. Slight clubbing of the fingers.

Fluoroscopy: Diaphragm fixed. Massive conglomerate shadows in upper part of each lung field with emphysema at bases.

Film: Note irregularity of the left diaphragm with obliteration of the costophrenic sinus. Marked emphysema in lower half of lung field.

Diagnosis: Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Moderate disability.

PLATE 24.—CASE A-1130. LITHUANIAN, AGE 55.

Occupational History: Came to the United States at 23 years of age. Mine laborer in anthracite, 3 years; contract miner for 23 years. Company laborer for past 6 years. Estimated time idle, 1 year.

Estimated Dust Exposure: (*a*) Weighted average, 390 million particles per cubic foot. (*b*) Million particle years, 12,522.

Past Medical: Chronic bronchitis, past 4 years. Two disabling colds per year. Head injury, mine accident in 1914.

Complaints: Constant cough for past 2 years. Occasional blood-streaked sputum. For past 6 years unable to hurry, and has marked shortness of breath. No loss of weight. Appetite good.

Physical Examination: Cyanosis and dyspnea without exercise. Chest expansion, 1½ inches. Expiration prolonged. Breath sounds harsh. Fremitus and impaired resonance generally. No persistent rales.

Fluoroscopy: Fixed diaphragm, irregularities on right; cardiac enlargement. Increased density in central lung field, more so on the left.

Film: Note extensive evidence of fibrosis, shadows not discrete, most marked on the left. Emphysema at bases and right upper one-third.

Diagnosis: Advanced anthraco-silicosis. Chronic pulmonary infection. Moderate disability.

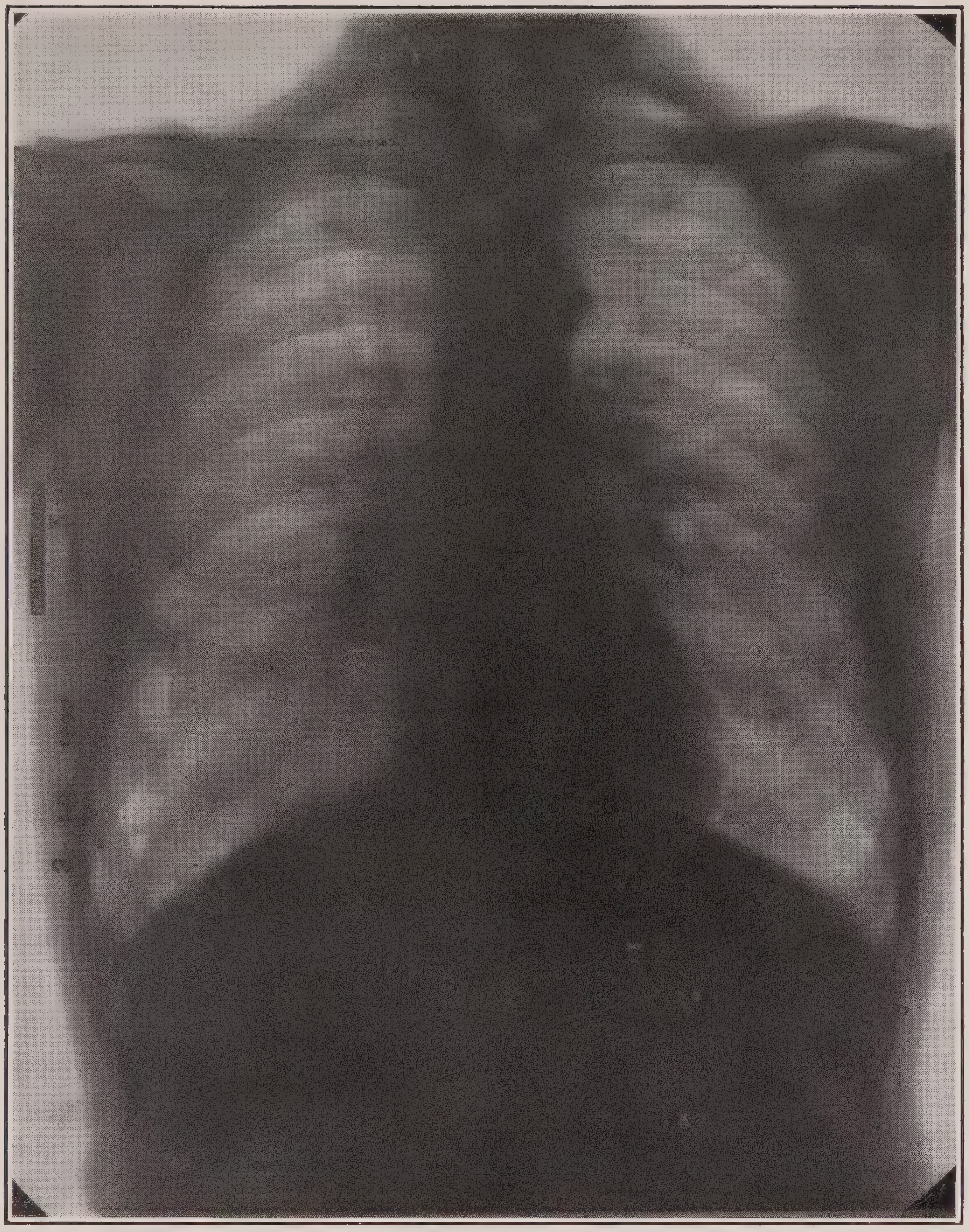


PLATE 25.—CASE D-18. POLE, AGE 74.

Occupational History: Farm work in Poland, 14 years. Coal loader in anthracite mine, 2 years. Contract miner, 38 years. Estimated idle, 4 years, and 2 years since working (6 years).

Estimated Dust Exposure: (*a*) Weighted average, 480 million particles per cubic foot. (*b*) Million particle years, 21,120.

Past Medical: Pneumonia as child in Poland. Pleurisy in 1927. Frequent chest colds in past 10 years.

Complaints: Shortness of breath past 10 years, so severe as to interfere with work last 7 years employed. Raised considerable thick yellow sputum. Unable to work for past 2 years because of shortness of breath.

Physical Examination: Emaciated, but does not appear to be 74 years of age. Blood pressure, systolic, 144; diastolic, 98. Marked dyspnea. Pulse 70. Respiration 24. Not exercised. Barrel chest. Retracted apices. Chest expansion ½ inch. Prolonged expiration. Breath sounds and fremitus generally decreased. Impaired resonance in upper two-thirds right and left. Occasional persistent crepitant rales over infra-clavicular region and over intrascapular area to level of fifth dorsal. Heart sounds weak but regular. Temperature 98.5.

Fluoroscopy: Diaphragm mobility moderately decreased. Hilar shadow increased in size and density. General increase in density upper two-thirds lung fields, right and left.

Film: Note symmetrical, diffuse nodular shadows, not discrete. Early coalescence.

Laboratory Examination: Sputum positive for acid-fast bacilli.

Diagnosis: Advanced anthraco-silicosis. Pulmonary tuberculosis. Marked disability.

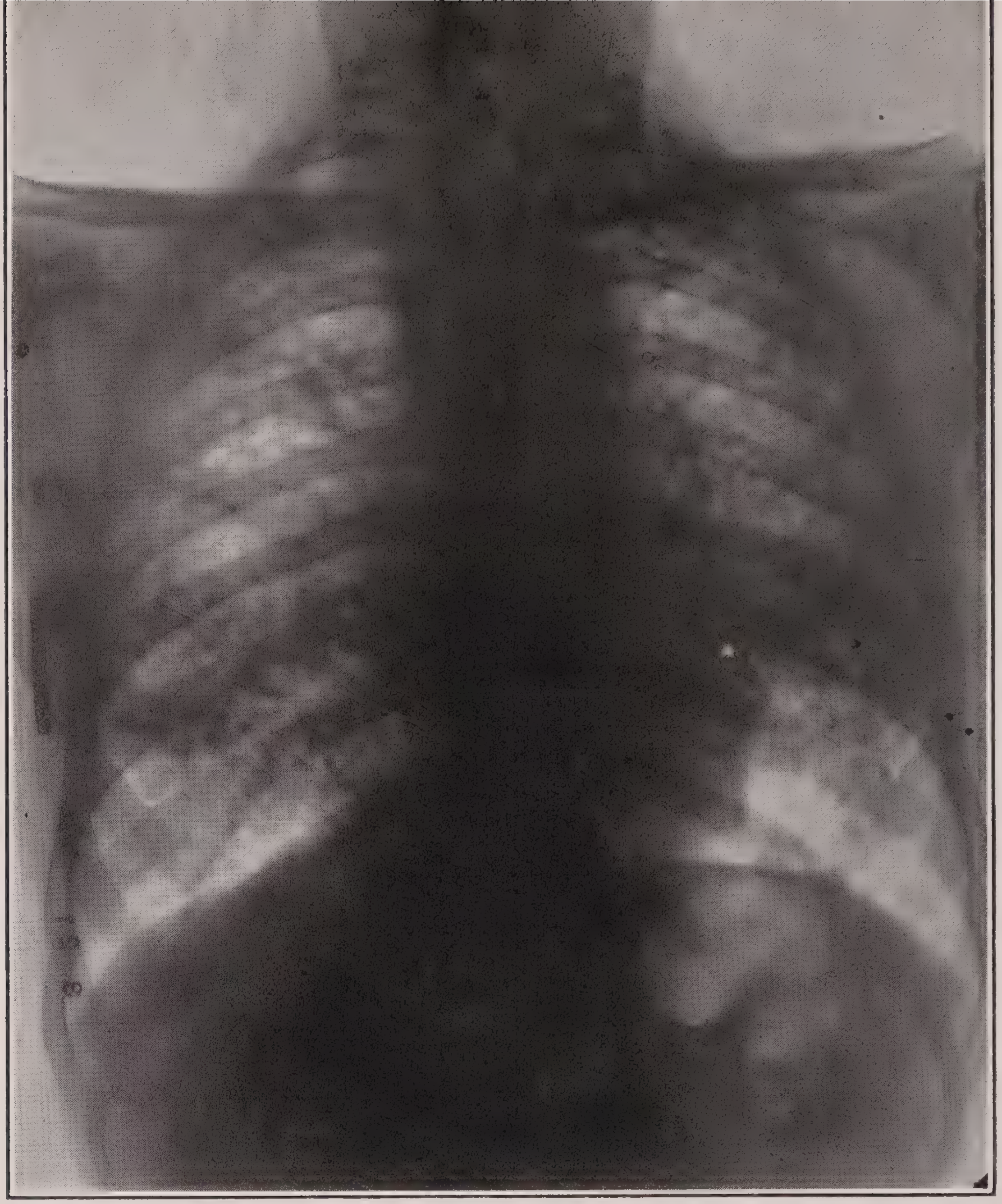


PLATE 26.—CASE D-45. HUNGARIAN, AGE 43.

Occupational History: Laborer in lumber yard, 3 months. Contract laborer in anthracite mines, 2 years. Contract miner, 8 years. Rock loading and drilling, 9 years. Rock contractor, instructing men, and working occasional shifts for 5 years.

Estimated Dust Exposure: (*a*) Weighted average, 360 million particles per cubic foot. (*b*) Million particle years, 6,969.

Past Medical: Attack of pleurisy in 1920, and occasionally since. Influenza in 1918. Frequent colds since 1919. Arthritis, right knee in 1931.

Complaints: Since 1931 has had considerable gastric disturbance. Treated for gastric ulcer for 2 years. Marked shortness of breath for 2 years. Chronic cough since 1931, increased in severity. For the past 6 months has raised large amounts of yellow frothy sputum, but no blood. Appetite failing. Has lost 35 pounds in 6 years. Numerous night sweats for past 6 months.

Physical Examination: An ill, emaciated individual. Weight 130 pounds. Blood pressure, systolic, 110; diastolic, 70. Marked dyspnea. Pulse 98, regular. Respiration 24, expiration prolonged. Not exercised. Chest expansion ½ inch. Marked evidence of muscular atrophy and prominent superclavicular fossae. Decreased fremitus and impaired resonance throughout, marked in the upper two-thirds. Breath sounds harsh. Persistent crepitant rales more marked in the uppers. No abdominal tenderness, but complains of pain in the epigastrium on deep inspiration. No fever.

Fluoroscopy: Limited diaphragmatic excursion. Numerous adhesions. Dilated aorta.

Film: Note marked evidence of emphysema, irregular diaphragm, and coalescing of shadows peripherally.

Laboratory Examination: Smears show occasional acid-fast filament (Nocardia). Culture, and guinea pigs inoculated, negative for tuberculosis.

Diagnosis: Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Marked disability.

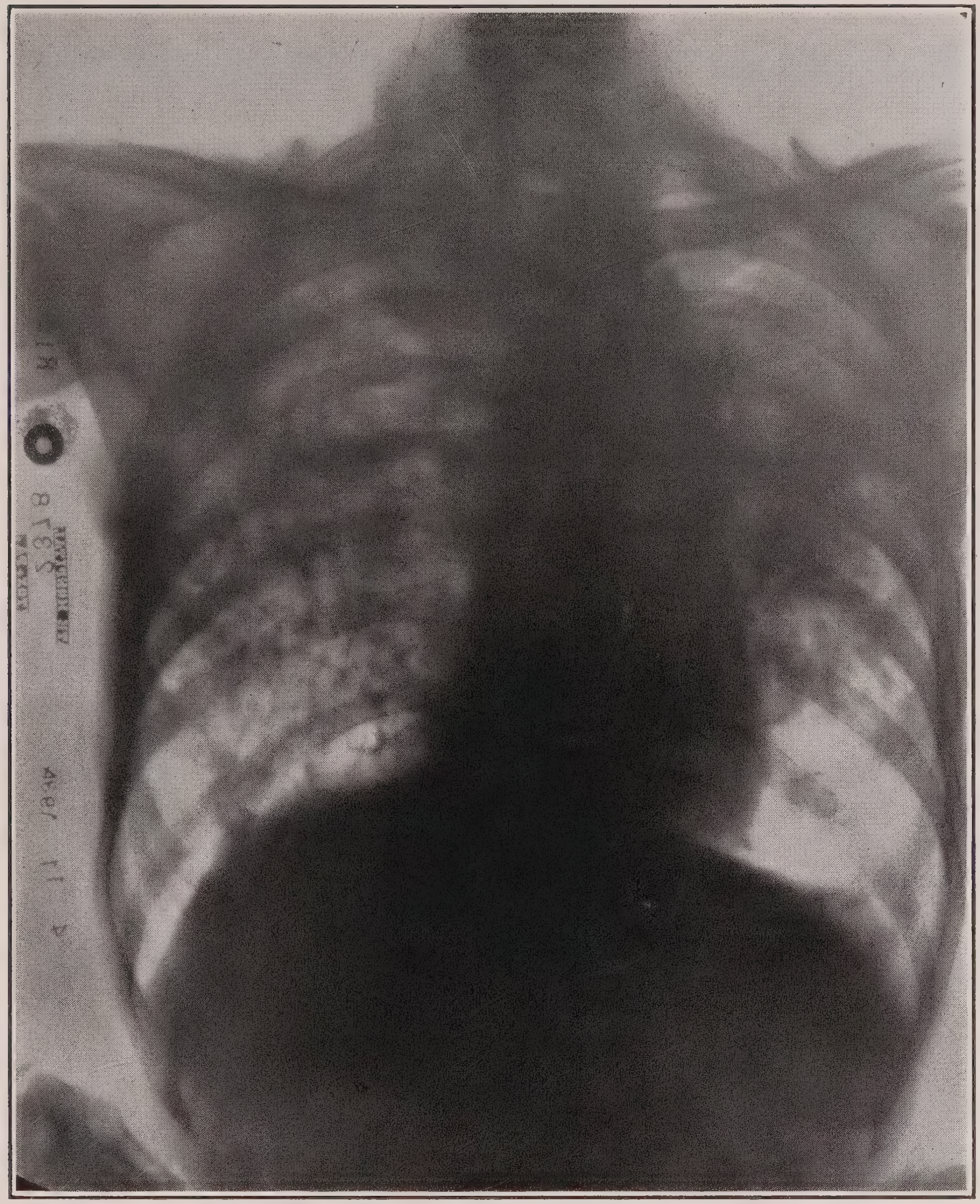


PLATE 27.—CASE D–9. POLE, AGE 64.

Occupational History: Laborer in roller mills (steel), 4 years; farm hand in Pennsylvania, 11 years; coal loader (underground, anthracite), 15 years; contract miner, 18 years. Unable to work for past 3 years.

Estimated Dust Exposure: (*a*) Weighted average, 480 million particles per cubic foot. (*b*) Million particle years, 20,600.

Past Medical: No serious illness until last 7 years, and since 1926 has suffered from severe colds on the average of 3 to 4 times each year.

Complaints: Shortness of breath for more than 10 years, which has interfered with work for about 7 years. Productive cough, much worse each succeeding year since 1926. Never has spit blood. Poor appetite past year.

Physical Examination: Ill and emaciated individual, unable to exercise, markedly dyspneic. Blood pressure, systolic, 110; diastolic, 92. Prolonged expiration. Flat chest, expansion 1 inch. Moderate kyphosis, retracted apices. Decreased breath sounds and impaired resonance generally. Persistent subscrepitant rales over both upper fronts. Slight cyanosis; marked clubbing of fingers.

Fluoroscopy: General increase in pulmonary density in upper two-thirds. Hilar shadow indefinite with conglomerate shadows to the left. Diaphragm fixed.

Film: Note marked emphysema at both bases, and increased density especially in the central lung fields. Irregular diaphragm.

Laboratory Report on Sputum: Negative for acid-fast bacilli.

Temperature: 99.5.

Diagnosis: Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Marked disability.

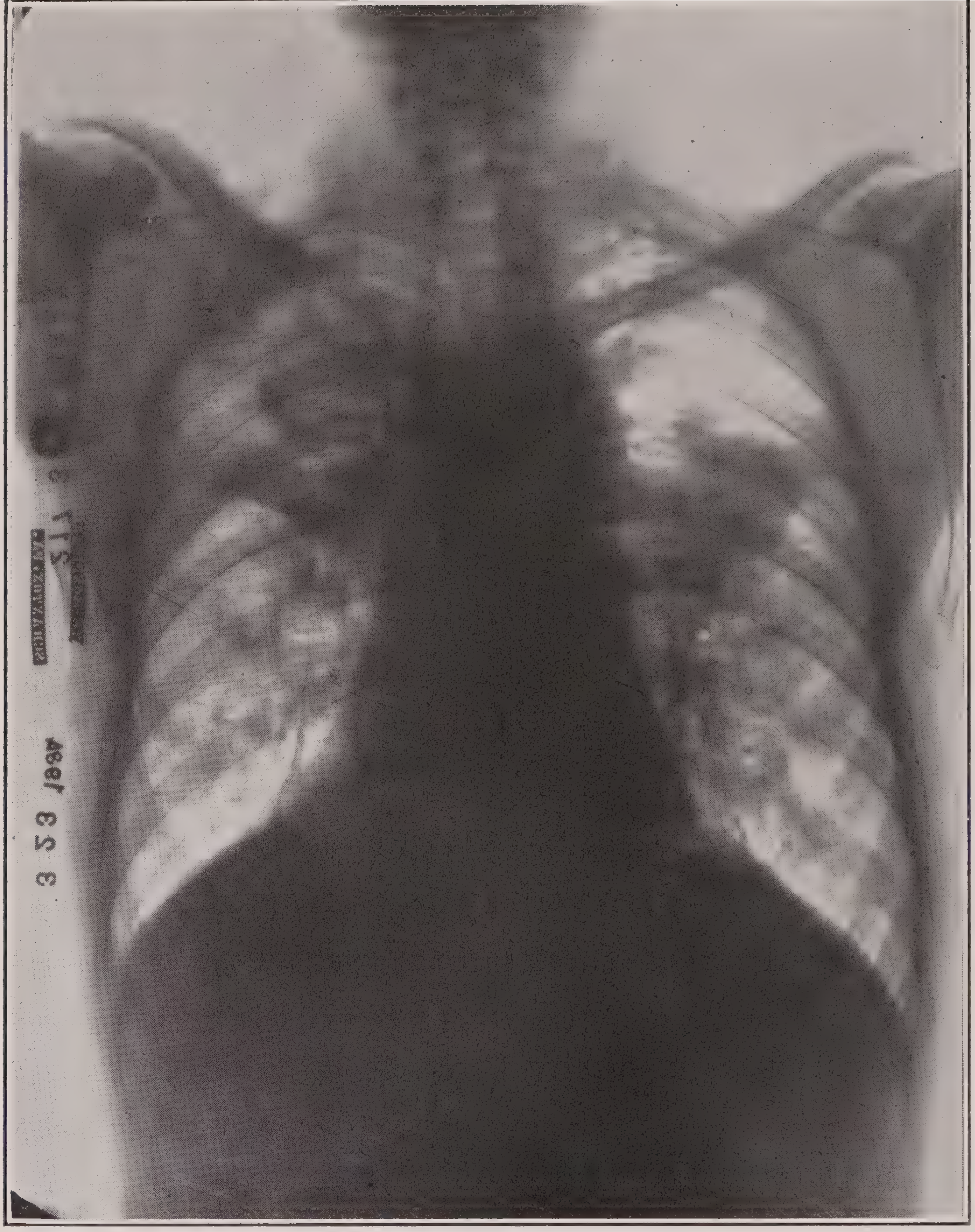


PLATE 28.—CASE D-54. ITALIAN, AGE 51.

Occupational History: Teamster for a coal company, 5 years. Coal loader in anthracite mine, 3 years. Contract miner, 17 years. Worked 18 months as driller and loader in rock tunnel. (Anthracite mine.) Used jackhammer for about 2 years.

Estimated Dust Exposure: (*a*) Weighted average, 462 million particles per cubic foot. (*b*) Million particle years, 9,240.

Past Medical: Frequent severe colds since 1924.

Complaints: Shortness of breath first noted about 1927. Forced to quit work because of respiratory trouble in 1928. Cough has been especially troublesome for past 2 years. Raises large amount of sputum mostly upon first getting up in the morning. Has never spit blood. Appetite is good. Has lost about 18 pounds in weight in past 4 years.

Physical Examination: Fairly healthy appearance, but looks older than age stated. Weight, 120 pounds. Blood pressure, systolic, 130; diastolic, 88. Dyspnea marked after walking length of ward (75 feet). Pulse 75; after slight exercise, 100. Respiration 22 before exercise, 26 after, but rate remained high and expiration was prolonged. Chest expansion, 2 inches. Retracted apices. General decrease in fremitus, hyper-resonant at both bases and left upper, but impaired above fifth rib right and left. Breath sounds harsh; sibilant and subcrepitant rales which persisted, both right and left. Moderate clubbing of fingers. Temperature normal during period of hospitalization.

Fluoroscopy: Limitation of diaphragm, right and left.

Film: Note evidence of dense fibrosis, enlarged hilar shadow, and diaphragmatic adhesion. Emphysema left upper and both bases.

Laboratory Examination: Negative for acid-fast bacilli.

Diagnosis: Advanced anthraco-silicosis with infection. Marked disability.

PLATE 29.—CASE D–26. ITALIAN, AGE 47.

Occupational History: Loader in anthracite mines, 1 year. Driller and loader in rock tunnel in anthracite mines, 1 year. Contract miner, 19 years. Last 8 years, half rock and half coal. Used jackhammer for 10 years.

Estimated Dust Exposure: (*a*) Weighted average, 470 million particles per cubic foot. (*b*) Million particle years, 9,720.

Past Medical: Frequent disabling colds since 1927.

Complaints: First noticed shortness of breath in 1927, which gradually increased. Marked productive cough developed, especially upon exertion in the forenoon. Poor appetite since 1921. Lost more than 20 pounds in weight. Pleurisy and night sweats for past 6 months. Unable to work for the past 5 years.

Physical Examination: Emaciated, ill individual. Marked dyspnea and prolonged expiration. Unable to exercise. Blood pressure, systolic, 142; diastolic, 92. Flat chest. Retracted apices. Chest expansion, 1 inch. Decreased fremitus. Impaired resonance over upper half of both lungs. Breath sounds decreased. Persistent crepitant rales below the clavicles anteriorly and over the intrascapulary area posteriorly. Temperature 99.

Fluoroscopy: Too ill to examine.

Film: Note the marked emphysema at the bases, pleural adhesions, and coalescing conglomerate shadow in the upper two-thirds.

Sputum: Negative.

Diagnosis: Advanced anthraco-silicosis. Clinical tuberculosis. Marked disability.

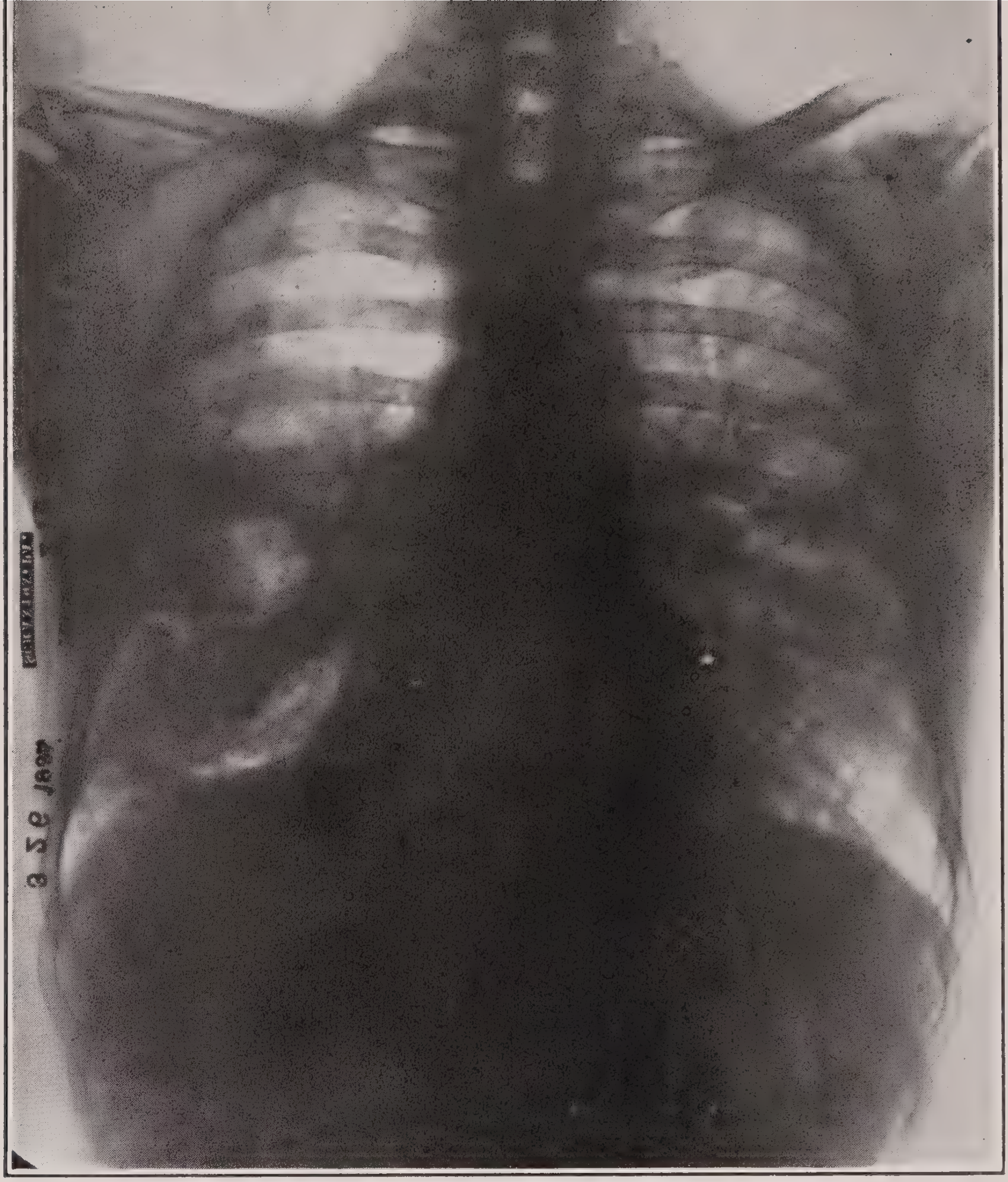


PLATE 30.—CASE D-59. AUSTRIAN, AGE 56.

Occupational History: Contract laborer in anthracite mines, 6 years. Contract miner, 20 years. Estimate of about 8 years spent in rock work. Used jack-hammer, 1 year. Idle about 2 years prior to 1932, totally disabled since then.

Estimated Dust Exposure: (*a*) Weighted average, 480 million particles per cubic foot. (*b*) Million particle years, 12,840.

Past Medical: Frequent chest colds for past 5 years.

Complaints: (Daughter has pulmonary tuberculosis, age 17). Shortness of breath interfering with work for 3 years before quitting work. Raises large amount of dark brown, watery sputum. Appetite has been poor for past 4 years. Spit blood occasionally last year. Occasional night sweats. Lost 15 pounds weight in last year. Unable to work for past 2 years.

Physical Examination: Florid face, slightly undernourished appearance. Weight, 130 pounds. Blood pressure, systolic, 184; diastolic, 110. Marked dyspnea. Pulse of 78, increased to 108 after getting up from bed, and remained over 100 for several minutes after reclining. Respiration increased from 20 to 30; expiration was prolonged. Chest expansion, 1½ inches. No marked change in fremitus. Percussion note impaired at bases. Breath sounds harsh, broncho-vesicular at right base. Persistent subcrepitant and crepitant rales, most marked over the right mid lung field anteriorly. Maximum temperature while in hospital, 100.

Fluoroscopy: Diaphragm fixed on the right and partially fixed on the left. Cavity in right lower lung field. Increased density throughout both lower lung fields. Hilus indefinite.

Film: Note emphysema in the right upper and left base areas. Cavity in the right lower lung field apparently drained before film was taken, as no fluid level is seen.

Laboratory Report: Sputum positive for acid-fast bacilli. Also guinea pigs inoculated, and sputum culture proved positive.

Diagnosis: Advanced anthraco-silicosis. Pulmonary tuberculosis. Marked disability.

FILM 1

PLATE 31.—CASE D–51. LITHUANIAN, AGE 62.

Occupational history.—Saloonkeeper, 6 years; contract mine laborer (anthracite), 2 years; contract miner, 26 years.

Estimated dust exposure.—(*a*) Weighted average, 480 million particles per cubic foot; (*b*) Million particle years, 13,440.

Past medical history.—Pneumonia in 1909 and 1912. Pleurisy since last attack of pneumonia. Frequent attacks of disabling colds since 1910.

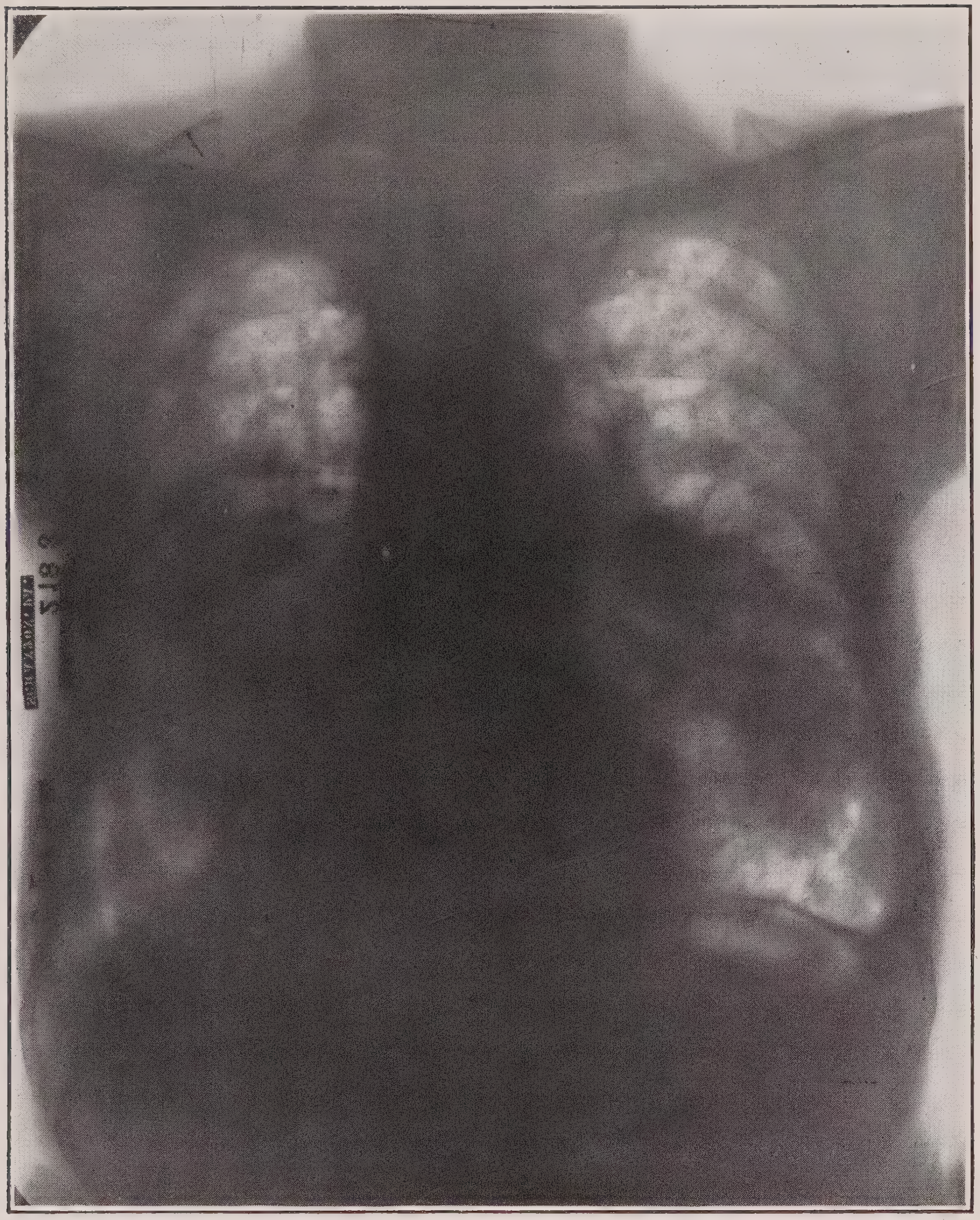
Complaints.—Unable to work for past 2 years. Shortness of breath since 1908, gradually worse. Productive cough for more than 15 years. Has spit blood occasionally past 2 years. Unable to sleep except in sitting position, for more than 1 year. Loss of 70 pounds in weight past 2 years.

Physical examination.—The physician caring for this man submits the following abstract of the physical examination made at the time he was forced to quit work 2 years ago: Chronically ill man. Marked respiratory embarrassment. Edema of lower limb. Weight 200 pounds.

Film 1.—(Taken May 1932.) Note marked emphysema. Coalescing of shadows in both bases. Drop type heart. Mediastinal traction to right.

Physical examination.—(Made in March 1934.) Very ill patient. Very emaciated, weight 130 pounds. Edema of lower limbs. Marked dyspnea. Pulse regular but weak, 110 per minute. Asthmatic breathing. Slight exertion caused severe coughing attacks. Expiration prolonged. Barrel-shaped chest. Expansion about 1 inch. Marked clubbing of fingers. Fremitus impaired, especially over lower chest. Impaired resonance. Broncho-vesicular breath sounds. Many persistent râles throughout entire chest. Area of cardiac dullness probably increased to right. No fever. Blood pressure, systolic 102, diastolic 70.

Fluoroscopy.—Heart enlarged and situated in the mid line. Massive conglomerate shadows involving both lower lung fields. Numerous diaphragmatic adhesions, excursions practically nil. Marked emphysema.



FILM 2

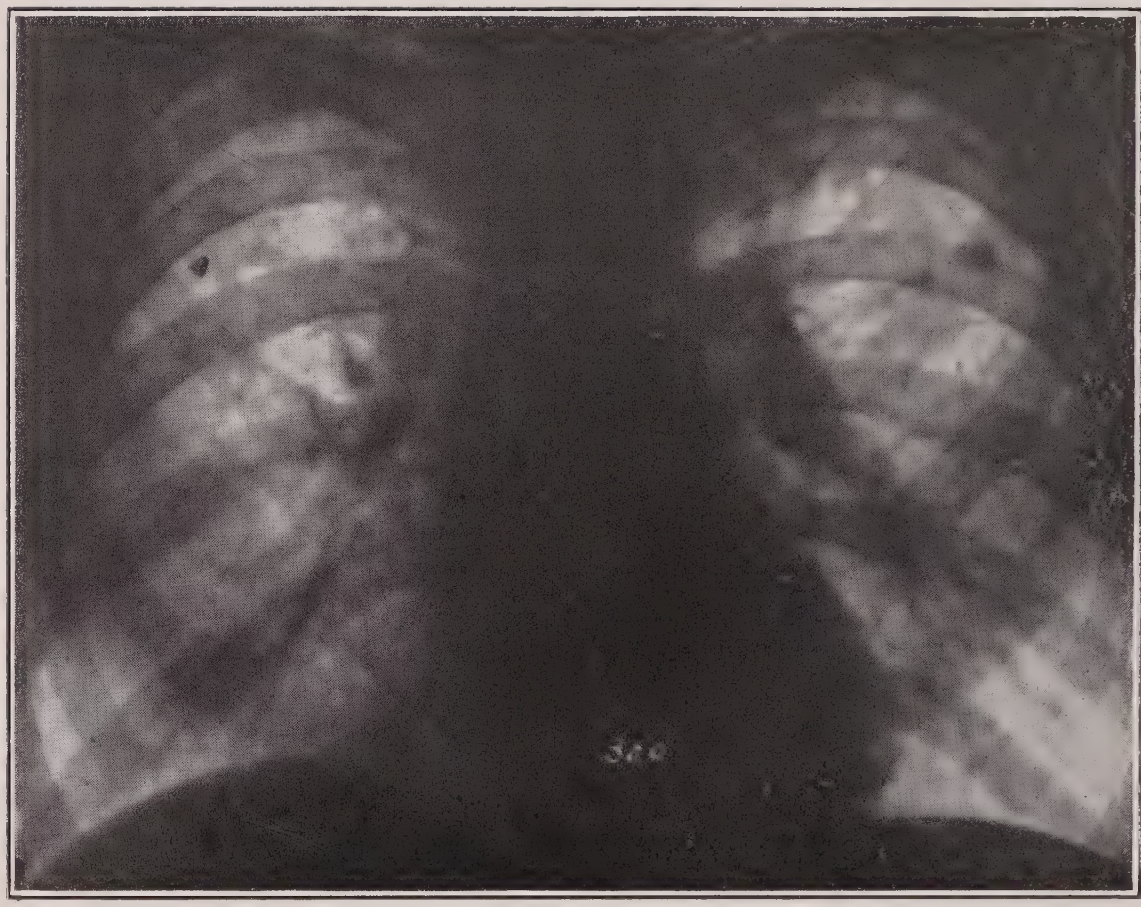
PLATE 31.—CASE D-51. LITHUANIAN, AGE 62.

Film 2.—(Taken March 1934.) Note increase in density and extent of shadows from the degree shown in film taken in 1932.

Laboratory.—Sputum negative for acid-fast organisms. Urinalysis shows numerous granular casts and a large trace of albumin.

Diagnosis.—Advanced anthraco-silicosis, with infection. Chronic myocarditis. Total disability.

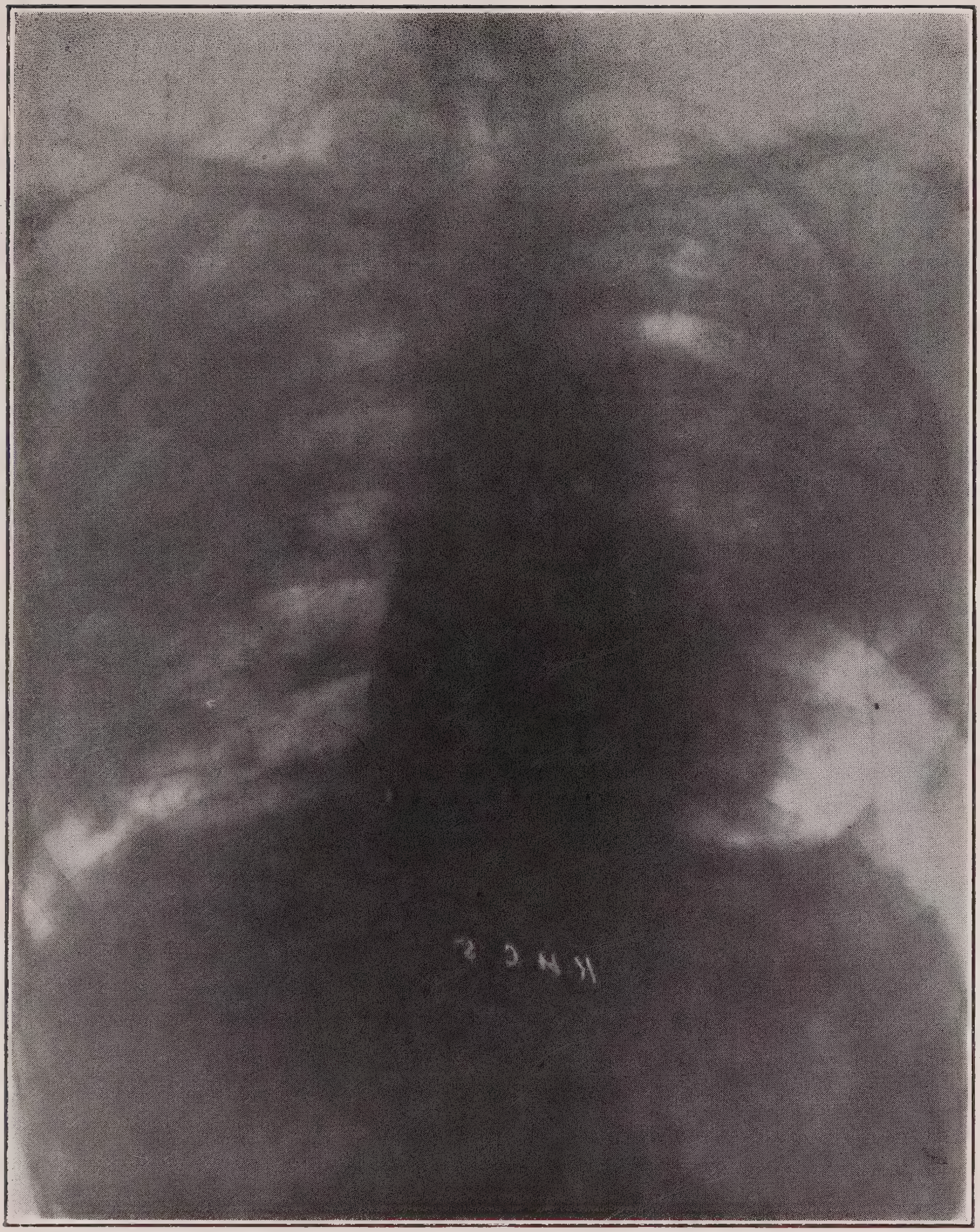
NOTE.—This patient died about 3 weeks after this last examination; physician in charge reported death due to miners' asthma and myocarditis.



FILM 1

PLATE 32.—CASE D-300:5. LITHUANIAN, AGE 42.

(See case history p. 65.)



FILM 2

PLATE 32.—CASE D–300:5. LITHUANIAN, AGE 42.

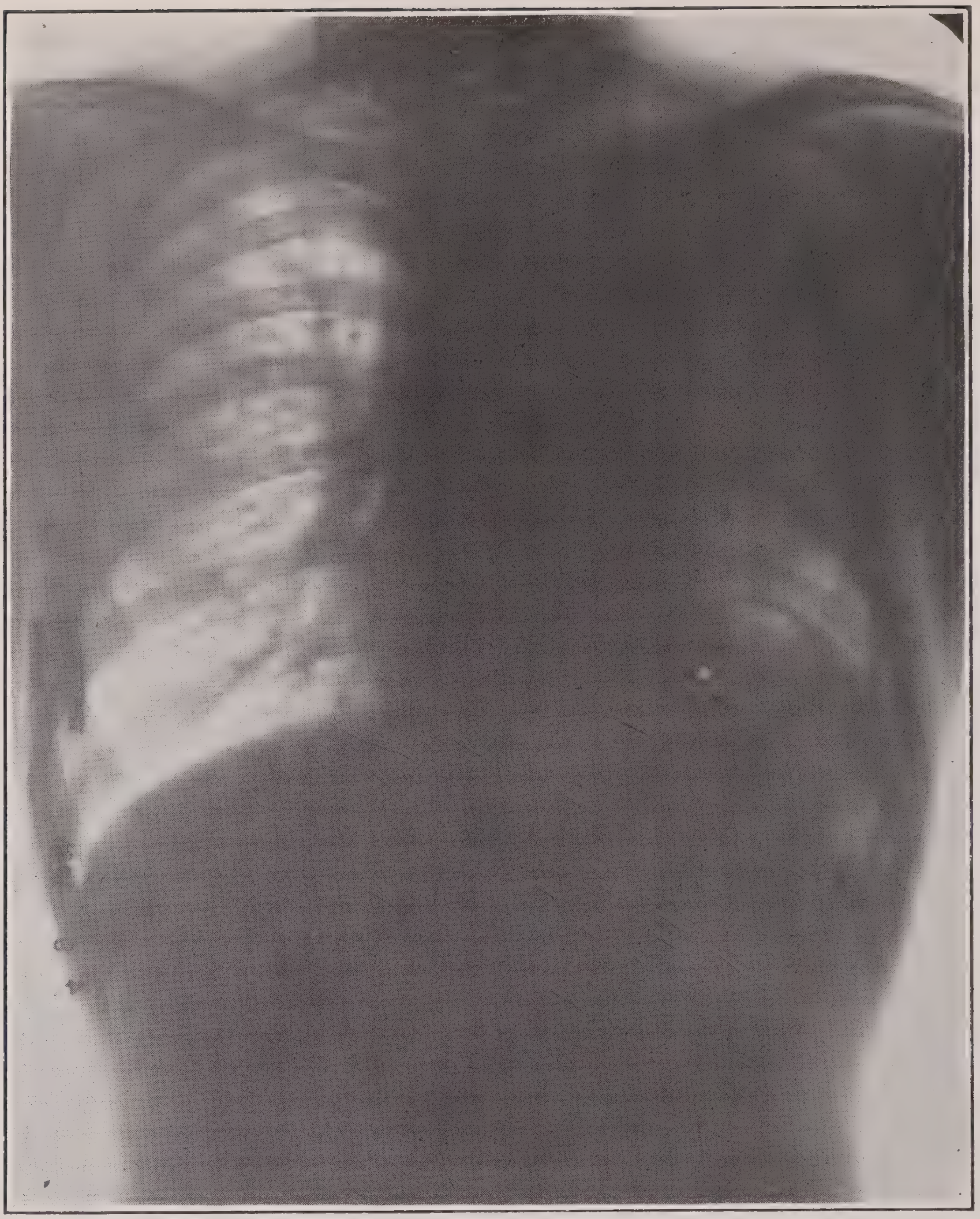


PLATE 33.—CASE D-83. WHITE, AGE 40.

Occupational History: Picked slate (dry breaker), 5 years. Mule driver, 3 years. Patcher, 2 years. Motorman, 11 years. Outside truckman at colliery, 1 year. Motorman, inside, 1 year. Truckman, outside, 6 years. (During 4 years as motorman inside, hauled and dumped rock in old workings.)

Estimated Dust Exposure: (*a*) Weighted average, 101 million particles per cubic foot. (*b*) Million particle years, 2,936.

Past Medical: Frequent colds past 10 years. Pleurisy in left chest, fall of 1931.

Complaints: Quit motorman job in 1924 because dust made his cold worse. Tried it again in 1926 for 1 year, but because dust seemed to increase his bronchitis, he returned to outside work. Has had dry cough for more than 7 years. Since attack of pleurisy, has gradually lost weight. (More than 30 pounds in past 3 years.) In 1932 noticed sensation of tightness in chest. Very short of breath upon exertion. Consulted many doctors—diagnosis of miners' asthma given. November 1933 spit up about a cup of blood. Referred to University of Pennsylvania Hospital, January 1934. Was diagnosed tumor of lung.

Physical Examination: Ill, emaciated individual. Too weak to attempt exercise of any sort. Pulse, 110 and irregular. Chest expansion, 2 inches, and no perceptible difference in expansion of lower chest. Breath sounds harsh over right lung field—diminished markedly over left upper two-thirds. No rales. Dullness on percussion over entire left lung except at base and axilla. Clubbing of fingers. Moderate cyanosis.

Fluoroscopy: Entire left lung field with exception of extreme base is one dense shadow. Left diaphragm raised.

Film: Note emphysema entire right with increase of linear marking and high diaphragm on left.

Laboratory Report: Sputum negative for acid-fast bacilli. Granular casts and albumin in urine.

Diagnosis: Lung tumor—type undetermined. Complete disability.

Comment: Patient died of profuse hemorrhage first week of July 1934. No autopsy obtained.

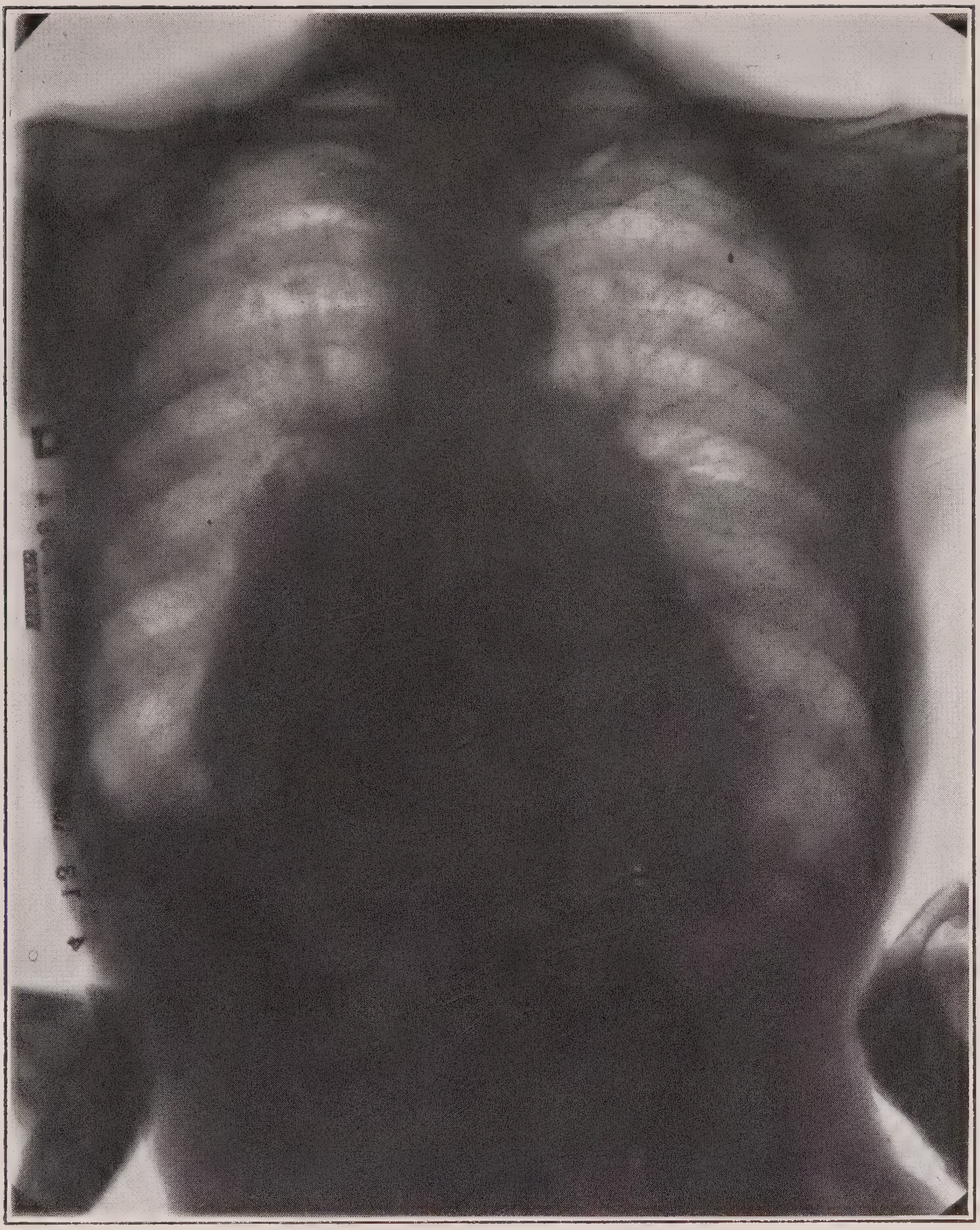


PLATE 34.—CASE D-40.—WHITE, AGE 61.

Occupational History: Slate picker (dry breaker), 1½ years. Door tender, 1 year. Mule driver and car runner, 7½ years. Contract laborer, 2 years. Contract miner, 24 years. Orderly in State insane asylum, 9 years. Orderly in almshouse 7½ years.

Estimated Dust Exposure: (*a*) Weighted average, 360 million particles per cubic foot. (*b*) Million particle years, 13,110.

Past Medical: Inflammatory rheumatism when 17 years of age. Bedfast for 3 months. Pneumonia and pleurisy in 1918. Patient in tuberculosis sanatorium, 5 months in 1918. Severe hemorrhage, pulmonary (?) in 1915.

Complaints: Quit mining because of shortness of breath. Constant pain in back; hacking cough. Occasional spitting of blood. Loss of 40 pounds of weight in past 8 years. Complete disability for past 2 years.

Physical Examination: Chronically ill patient. Unable to exercise. Very emaciated. Marked shortness of breath. Pulse, irregular and weak. Loud systolic murmur. Marked clubbing of the fingers. Barrel chest. Chest expansion, 2 inches. Many rales at both bases. Liver palpable two fingers below costal margin; edema of lowers.

Fluoroscopy: Note marked increase in heart shadow. Obliteration of costophrenic sinuses.

Laboratory Examination: Moderate secondary anemia. Large trace of albumin. Negative von Pirquet.

Diagnosis: Organic heart disease with decompensation; chronic nephritis. Anthraco-silicosis.

CASE D–300:5. LITHUANIAN, AGE 42. EXAMINATIONS JULY 1933 AND APRIL 1934

Occupational history.—Laborer, anthracite mines (underground) 3 years, contract miner, 17 years; company miner past 3 months (changed occupation due to physical condition).

Estimated dust exposure.—(*a*) Weighted average, 480 million particles per cubic foot; (*b*) million particle years, 10,560.

Past medical.—Pneumonia in 1932; influenza, 1932. Frequent disabling colds past 3 years.

Complaints.—Marked productive cough; loss of 10 pounds in weight past year; unable to continue strenuous work; appetite failing.

Physical examination.—Well-developed individual. Shortness of breath apparent before exercise which he was not able to complete. Pulse remained high after exercise, and expiration was prolonged. Chest expansion 1½ inches; emphysematous type chest and prominent supra-clavicular fossae. Clubbing of the fingers. Fremitus increased and percussion note impaired above the level of the third rib and fifth thoracic spine. Persistent sibilant and subcrepitant râles over upper fronts and intrascapular area posteriorly.

Fluoroscopy.—Moderate limitation of the diaphragm with a sharp peak on left seen by lateral view. Both apices hazy; increase in size and density of hilar shadow.

Film 1.—Note increase in linear markings extending to the periphery. Also increase in density toward the apices. Emphysema most marked at left base. (Peaking of the diaphragm on the left not shown in film.)

Diagnosis.—Anthraco-silicosis with infection. Moderate disability.

Examination April 1934.—Unable to do any work for past 8 months. Feels very weak. Constant choked feeling. Loss of about 20 pounds in weight past 6 months. No appetite. Thinks he has a fever every day. No blood in sputum, but marked increase in the amount raised. Considerable chest pain, especially after morning coughing attacks.

Physical examination.—Ill, emaciated individual. Marked shortness of breath, cyanotic lips and fingertips. Blood pressure, 138 systolic and 80 diastolic. Pulse regular, about 80 per minute. Asthmatic breathing. Muscular atrophy. Increase in chest findings from previous examination. No area of lung fields free of persistent râles. No fever.

Fluoroscopy.—Not satisfactory because of the condition of the patient.

Film 2.—Note marked increase in the pulmonary changes during interval since first examination (9 months). Emphysema is more marked. Conglomerate shadows in both lung fields. Irregularities of the diaphragm, most marked on the left. Note peak not shown in previous film, but reported on the fluoroscopic examination.

Laboratory examination.—Sputum shows no acid-fast organisms. (Only three specimens studied). Urinalysis showed no albumin, sugar, or casts.

Diagnosis.—Advanced anthraco-silicosis. Clinical pulmonary tuberculosis. Marked disability.

DISABILITY FROM CAUSES OTHER THAN MINERS' ASTHMA

Three case histories with accompanying films are submitted as representative of pathological conditions sometimes diagnosed as miners' asthma, but in which some other disease appears to be the major cause of disability. The local physicians referring these cases reported that they had considered them at first as cases of miners' asthma, but had changed the diagnosis after more careful study.

In the first and second cases there is evidence of a certain amount of pulmonary fibrosis, and the occupational and medical histories are suggestive of miners' asthma, but the initial signs, course, clinical and X-ray examinations indicated that the pathological conditions found were not due to pulmonary fibrosis developing from exposure to anthracite dusts. In the third case there is more evidence of pulmonary fibrosis, and no doubt this condition would aggravate an existing heart disease; nevertheless, there appears to be insufficient evidence for a definite conclusion that the disability resulted from pulmonary fibrosis per se.

CASE D–27. POLE, AGE 47

Occupational history.—All work underground in anthracite mines. Mule driver 2 years. Patcher 2 years; contract miner 19 years; used jack-hammer 6 months. Motorman 2 years; rope rider 2 years; loader, 2 years.

Estimated dust exposure.—(*a*) Weighted average, 354 million particles per cubic foot. (*b*) Million particle years, 10,264.

Past medical.—Frequent colds since 1930; three especially severe attacks in the fall of 1931.

Complaints.—Shortness of breath noted past 3 years. Severe pleurisy past 2 months. Claims total disability past 2 months. Detailed history of health past 4 months, abstracted as follows: Tooth pulled in November, patient being under general anesthesia about 1 hour. Irritative cough present since. Three weeks later severe cold in chest. High fever. Delirium several days. Family could secure no medical care. Has spit blood since height of this attack. Some improvement until second week in January when severe, cutting pain in left chest occurred. High fever. Marked shortness of breath. Spit up about 1 pint of blood 2 weeks before this examination. (February 1934).

Physical examination.—Well-developed and nourished individual. Marked respiratory distress. Appears acutely ill. Temperature 102. Pulse 90. Left chest lags upon inspiration, and effort to breathe deeply limited because of pain. Dullness left base and axilla. Breath sounds decreased at extreme base, but exaggerated between third and sixth rib, and in axilla. Persistent crepitant râles over this area. Chest expansion one-half inch. Effort cut short. Findings suggest fluid or thickened pleura at left base with consolidation in middle and upper portions of lower lobe. Coarse broncho and broncho-vesicular breathing and evidence of consolidation suggest delayed resolution of acute pneumonia process, and possibly cavity formation.

Fluoroscopy.—Area of increased fullness continuous with left hilar shadow; in central portion, cavity with fluid level demonstrated.

Film.—Note decrease in linear marking throughout. Rather granular appearance generally. Slight generalized emphysema; central area in left lung field shows increased density and cavitation.

Laboratory report.—Sputum negative for acid-fast organism.

Diagnosis.—Pneumonia; lung abscess.

Comment.—Reported first stage of anthraco-silicosis, with area of increased density left hilar and middle lung field suggesting possibility of neoplasm. Advised bronchoscopic examination. The history and physical examination of this case present an example of the difficulties associated with proper classification of these individuals. Aside from the local changes in the left lung field shown on physical examination, one could not be justified in rendering a diagnosis of

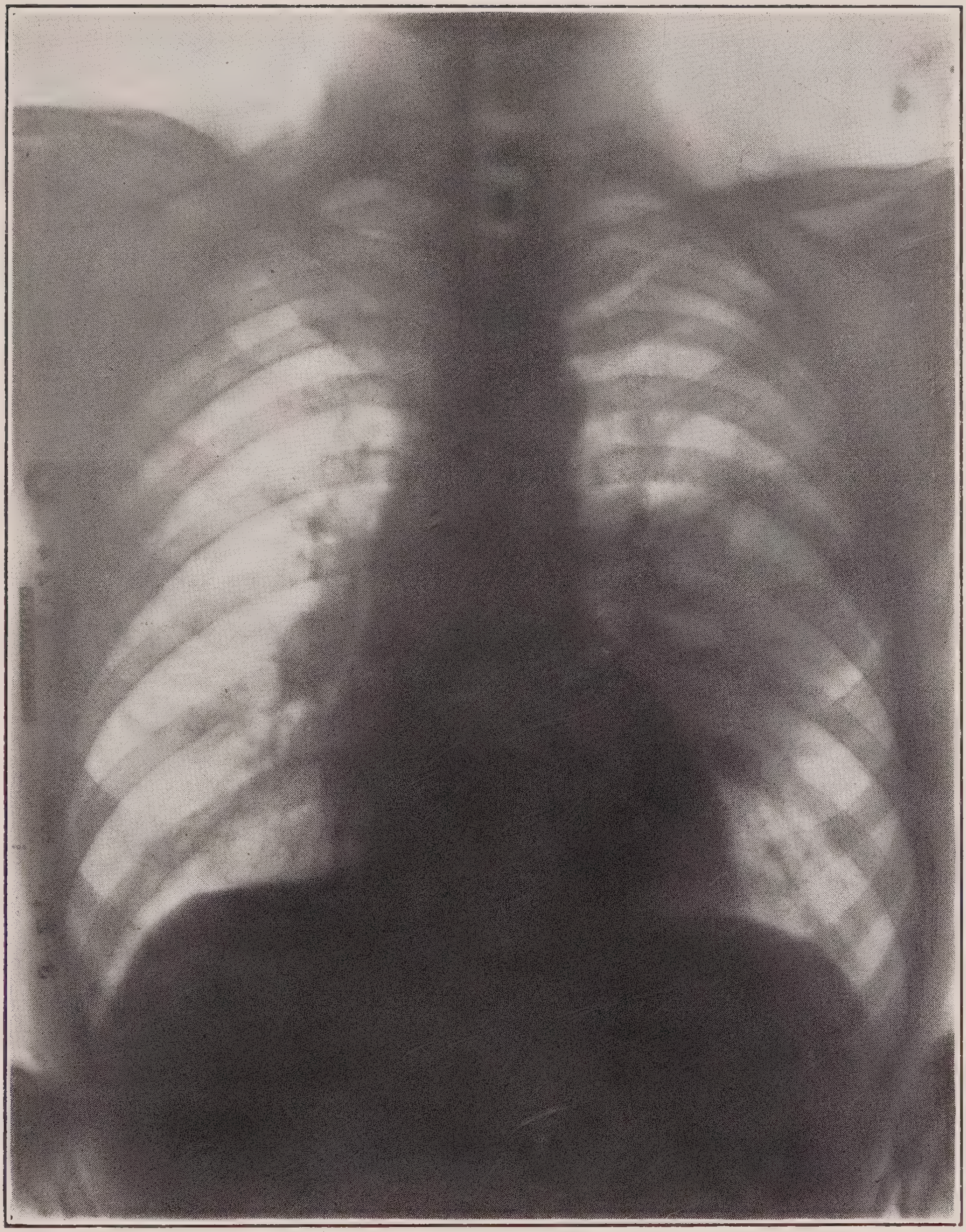


PLATE 35.—CASE D–27. POLE. AGE 47.

(See case history pp. 66–67.)

pulmonary fibrosis sufficient to cause decreased capacity for work. The history of present illness and physical examination findings are quite typical of a lung abscess following the pneumonia resulting from aspiration of purulent material at the time of the tooth extraction under general anesthesia. Whether sufficient changes are generally found in the lung to lower the patient's resistance to acute pneumonia is purely a matter of opinion.

5. URINARY SILICA IN ANTHRACITE COAL MINERS[16]

Throughout this report the term "anthraco-silicosis" has been used to describe the lung changes associated with the inhalation of anthracite coal with silica dust. As justification for the use of this term attention is called to the findings in connection with the dust exposure of the mine workers (which showed the presence of a certain amount of silica in the dust found in the air of the various workplaces), and pathological studies of lungs which were found to contain silica and carbonaceous material in excess of the amounts present in normal lungs. As a further substantiation of the fact that the condition found among these men may be attributed in part to the silica dust to which they were exposed, attempts were made to recover silica in the urinary excretion of the men in accordance with the methods used by King, of the University of Toronto, in his studies on the metabolism of silica. King has shown that gold miners exposed to the inhalation of dust containing silica excrete on an average twice as much silica as do persons not so exposed (*13*).

Accordingly, 103 men employed in two of the mines under study were examined for urinary silica. These men were selected on an occupational basis so as to include different exposures to silica dust, i. e., rock workers, chamber and pitch miners, breaker men, outside men, and transportation workers. The following tabulation indicates the relationship found between the amount of silica dust inhaled over a specified number of years, and the silica recovered in the urine:

Dust exposure in millions of silica particle-years	Average silica excretion in milligrams per 100 cc of urine
Less than 500	1. 7
500–999	2. 9
1000–1999	3. 4
2000 or more	3. 6

In addition to the group of actively engaged miners, 20 former miners were studied who had been exposed to anthracite dust for 37 years (average), and who had been out of the industry for 7 years (average). These men were found to be excreting about twice the amount of silica as do normal persons. Normal individuals have been shown to excrete an average of about 1 milligram per 100 cc of urine.

[16] The determinations of silica in the urine and lung specimen were made by Associate Chemist F. H. Goldman.

It was also shown that those who had been out of the industry the longest were excreting relatively less silica than the men out 5 years or less.

Evidence is not available to determine the value of knowledge of the amount of silica in the urine in making a diagnosis of anthraco-silicosis. Excessive silica excretion probably merely indicates an abnormal intake of silica. It does furnish, however, additional evidence of the etiology of the disease discussed in this study.

6. SUMMARY OF REPORT ON PHYSICAL CONDITION OF THE MEN

Study of the physical condition of anthracite-coal-mining employees included an occupational history, a medical history, a record of present complaints of ill health, a physical examination with special reference to the respiratory system, and a roentgenological examination of each of the 2,711 employed men who cooperated in this phase of the investigation. Supplemental observations were made on a group of 135 disabled ex-miners on none of whom had a definite laboratory diagnosis of pulmonary tuberculosis been made. A limited number of pneumoconiotic patients were studied at a State tuberculosis sanatorium for the purpose of obtaining additional information about the course of the disease, especially in its later stages.

About 23 percent of the men examined were diagnosed as having anthraco-silicosis. Most of these men were in the first stage of the disease. History of past illnesses revealed more attacks of pleurisy, pneumonia, and severe colds among the anthraco-silicotics than among an equal number of those not having the disease.

The cardinal symptom of anthraco-silicosis was found to be shortness of breath. The physical examinations also revealed that prolonged expiration, change in contour of the chest, decreased chest expansion, clubbing of the fingers, change in breath sounds, altered fremitus, and impaired resonance were signs of the disease. Definite lung changes were demonstrated roentgenologically in all cases diagnosed as anthraco-silicosis. Usually the lung changes thus revealed corresponded with the amount of physical impairment found.

About 63 percent of those having anthraco-silicosis showed evidence of disability, as compared with less than 10 percent in the control group. Moderate and marked degrees of disability handicapped approximately 21 percent of those with anthraco-silicosis, as compared with less than 2 percent of the men serving as controls.

A provisional diagnosis of clinical pulmonary tuberculosis was made on 6 percent of the coal-mining employees examined. The average prevalence of pulmonary tuberculosis in the general adult male population of the country is approximately 2 percent. Among

the nontuberculous anthracite workers, exclusive of the control group, about 20 percent were diagnosed as having some other respiratory disease; in the control group only 6 percent had nontuberculous respiratory disease.

The clinical picture presented by men having pneumoconiosis plus pulmonary tuberculosis as observed in a State sanatorium for tuberculosis exhibited certain noticeable differences in comparison with cases of tuberculosis uncomplicated by pneumoconiosis.

Thirty-five case histories with chest films covering disabled ex-miners as well as active employees of the coal-mining companies have been presented to show the clinical and roentgenological findings in representative cases.

The relationship found between the amount of silica dust inhaled over a period of years, and the amount of silica excreted in the urine of anthracite workers furnished additional evidence of the etiology of the disease under consideration.

V. PATHOLOGICAL FINDINGS IN ANTHRACO-SILICOSIS [17]

Specimens for pathological study were furnished through the courtesy of physicians practicing in the anthracite coal region of Pennsylvania. None of the cases used in the description of lung pathology was complicated by tuberculosis.

1. CHARACTERISTICS OF PATHOLOGY OF ANTHRACO-SILICOSIS

The pathology of anthraco-silicosis is characterized by the presence of large amounts of coal dust in the lungs, accompanied by an excessive amount of fibrosis.

Grossly, the lungs are dark gray in color, and are usually heavy. The coal dust appears to collect up to the subpleural connective tissue. In early cases a fine, black, linear network appears on the surface of the lungs where the dust has been deposited. The external surface may appear spotted with light gray areas where the pleura has thickened. In advanced cases thickening of the pleura is usually encountered. Scattered tough, fibrous adhesions, rarely diffuse, attaching the visceral to the parietal pleura, are seen in varying numbers. The interlobar pleurae are often fused. The lobes involved are distorted and contracted, the degree depending on the amount of fibrosis present. The lungs are firm, and nodules of varying sizes may be felt. Palpable crepitus occurs in scattered areas or may be entirely absent. Emphysematous blebs, often of large size, are seen in advanced cases.

On section the appearance of the cut surface varies with the extent of the process. In early cases irregular, stellate, black, fibrous

[17] By J. W. Miller, acting assistant surgeon.

nodules, and linear black markings are noted throughout the lungs. The nodules are most numerous in the upper portions of each lobe, and the upper lobes usually are the more involved. Between the black nodules the lung tissue appears more or less normal. As the condition progresses, the nodules become larger. The increase in size is not uniform, as nodules of varying sizes and shapes occur. These nodules become confluent, presenting large, black-to-gray areas of consolidation, most frequent in the upper portions of the lobes. The apex of the lung is often free of nodules. These coalesced nodules have the appearance and consistency of black rubber. Strands and whorls of gray fibrous connective tissue are noted on their dryish cut surfaces. The appearance may be laminated, but the outer margins are irregular. Occasionally a central area of pasty, noncaseous necrosis, often with cavitation, is present in these masses. The walls of the cavities are rough and irregular, with protruding strands of fibrous tissue. In advanced cases the lung tissue between the black fibrous masses may be congested, edematous, or emphysematous. A compensatory emphysema, often involving large areas of a lobe, is usually present. Very large emphysematous blebs ranging from 0.5 to 4.0 centimeters in cross section are occasionally seen. The walls of the bronchi and blood vessels appear thickened in advanced cases. The peritracheal and pulmonary lymph glands are large, firm, and black. Interlacing strands of gray fibrous tissue occur in their matrices. Matting of the lymph glands is rarely noted in cases uncomplicated by infection.

2. MICROSCOPIC APPEARANCE OF LUNG SPECIMENS

Black particles of coal dust are seen in macrophages (large mononuclear leucocytes) in the alveoli. Free dust particles in the alveoli and particles in the alveolar epithelial cells are rarely seen. Collections of dust-bearing macrophages are noted in the perivascular and peribronchial lymphatics and the adjacent interstitial connective tissue. A fibrous hyperplasia is present along the lymph channels, which, in portions so increases as to form nodules that appear as concentric masses and irregular diffuse areas. In the centers of some of the smaller nodules are noted compressed and hyalinized blood vessel walls. The centers of the larger nodules are often free of appreciable amounts of coal dust, and are of well-formed, white fibrous connective tissue. Hyaline degeneration is frequently seen. Collections of dust-laden macrophages are present at the periphery of these nodules, but free extracellular coal dust in large quantities is noted in the adjacent underlying area of dense connective tissue. When the nodules become confluent, the peripheral depositions of coal dust become enclosed in the larger nodule so formed. Areas of central, amorphous, finely granular necrosis are sometimes seen.

The peritracheal and pulmonary lymph glands show a fibrous hyperplasia and dense depositions of coal dust, often so marked as to obscure the histology of the organ.

3. PATHOLOGICAL FINDINGS COMPARED WITH THOSE IN SIMILAR STUDIES

The pathological findings in the lungs studied in this series are in agreement with those in a similar study by Cummins and Sladden (*14*).

Animal experiments have shown that anthracite coal dust, when injected into the peritoneal cavity of guinea pigs, remains practically inert, the particles being encapsulated and phagocytized by the cells of the peritoneum or its underlying connective tissue (*15*). The amount of dust noted in 360 days after injection was found to be the same as that observed in 7 days. Very little fibrosis was produced in addition to that necessary to handle the dust as a foreign body. This would seem to indicate that the extensive amount of fibrosis found in the lungs examined was due to the silica in the rock associated with the coal.

The pathology of anthraco-silicosis as observed in these cases is essentially a deposition of coal dust in the lungs, accompanied by an extensive fibrosis, both diffuse and nodular, with associated functional and degenerative changes.

4. CHEMICAL EXAMINATION OF PATHOLOGICAL MATERIAL

Ash and total silica determinations were made on six specimens of lung tissue received from the anthracite coal region. One hundred grams of dried tissue, selected from representative portions of the lungs were used in making the analyses.

King reports 0.14 percent (140 mg per 100 gm dried tissue) as the normal silica content of human lungs (*16*). McNally gives 0.113 percent (1.13 mg per gm dried lung tissue) as the normal found in his studies (*17*).

The results of determinations made on the six specimens from the anthracite coal field are shown in the following table.

TABLE 26.—*Ash and total silica determinations on 6 anthraco-silicotic lung specimens*

Case number	Percentage ash	Percentage free and combined silica	Percentage silica (total) in ash
1	10.40	1.20	11.80
2	5.58	1.52	27.24
3	8.45	1.75	20.30
4	6.59	1.76	26.70
5	5.03	1.22	24.27
6	6.02	1.86	31.15

In one case separate determinations were made on the solid, black, nodular portion of a lung from an advanced case of anthraco-silicosis, and on a less involved portion of the same lung in which some aerated tissue was present between small, black, fibrous masses. The solid portion showed ash 11.7 percent, free and combined silica 2.5 percent, and silica in the ash 21.4 percent. The less involved portion showed ash 5.2 percent, free and combined silica 1 percent, and silica in the ash 19.2 percent. It will be seen that the ash and silica in the first specimen were more than twice as much as in the second specimen, yet the percentage of free and combined silica in the ash of both specimens was about the same.

Separate determinations were made on both right and left lung in two of the cases. The results were as follows.

TABLE 27.—*Ash and total silica determinations on right and left lung of 2 anthraco-silicotic specimens*

Case number	Lung	Percentage ash	Percentage free and combined silica	Percentage silica in ash
5	Right	4.99	1.28	25.73
5	Left	5.08	1.16	22.82
6	Right	6.02	1.90	31.13
6	Left	5.84	1.82	31.17

It can be seen from these two cases that there is little variation in ash and silica in each lung from the same case.

For comparison the results of Badham (*18*) and of Cummins and Sladden (*14*) are given below. Minimum and maximum figures are shown for three groups of coal miners.

TABLE 28.—*Ash and total silica determinations on lung specimens from coal miners in 3 different countries*

Investigator	Coal field	Percentage			
		Ash		Total silica	
		Minimum	Maximum	Minimum	Maximum
Badham	New South Wales	2.38	8.85	0.22	1.53
Cummins	South Wales	4.40	12.42	.42	4.28
U. S. Public Health Service	Pennsylvania anthracite	5.03	10.40	1.20	1.86

No definite conclusions have been drawn from this limited number of cases. However, the variations shown in the ash and silica determinations on anthraco-silicotic lung tissue examined from Pennsylvania hard-coal miners are within the limits found by other investigators, and the pathological changes in the lungs are associated with the presence of excessive amounts of silica.

PLATE 36.—CASE 1. RIGHT LUNG.

Indurated, rubbery mass of fibrous tissue, heavily pigmented, involving practically all of upper and middle lobes. Scattered areas of pigmented, nodular, and diffuse fibrosis in remaining lung tissue. Large, indurated, heavily pigmented lymph glands at hilus. Slight emphysema in lower lobe and base. Markedly thickened pleura with many fibrous adhesions.

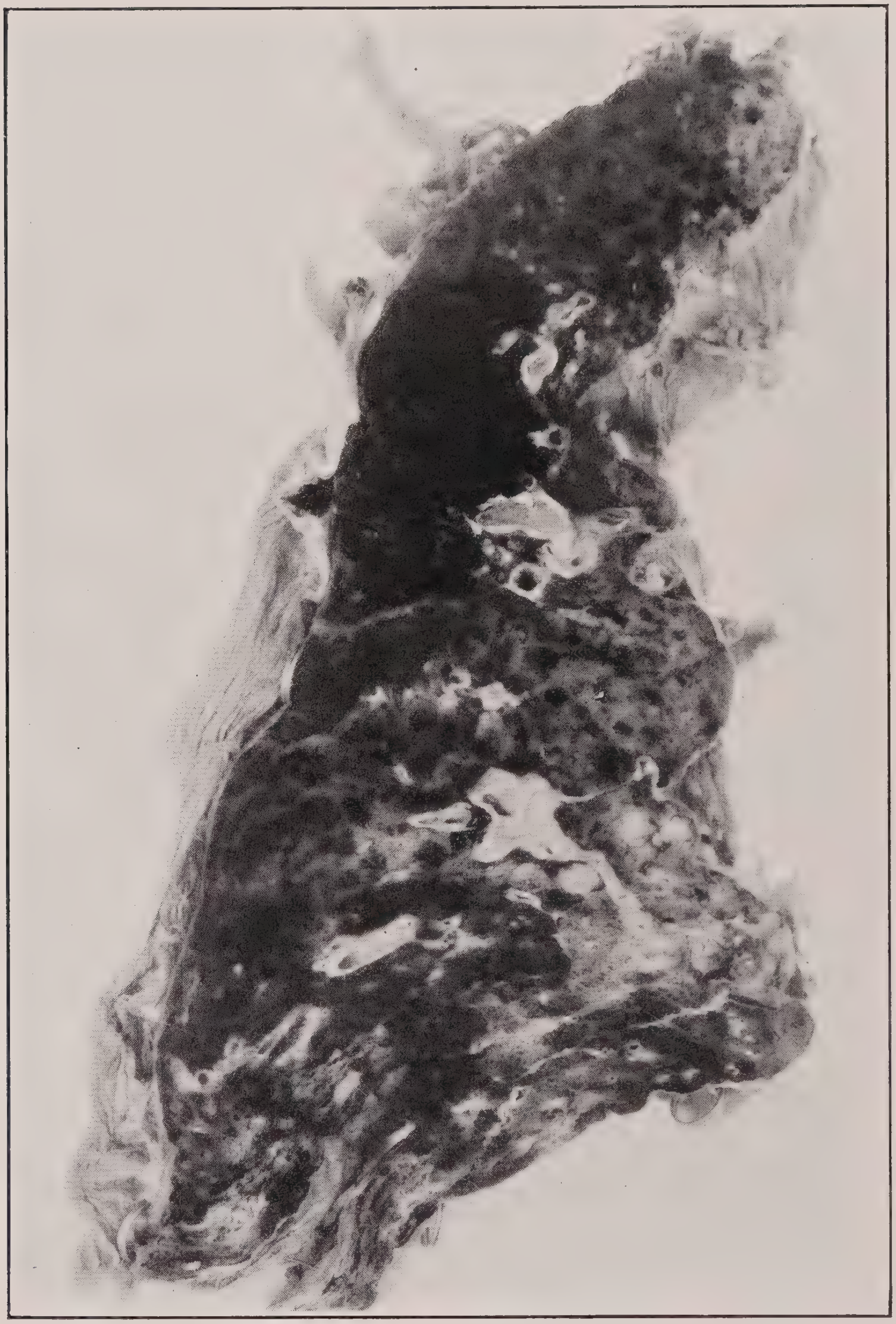


PLATE 37.—CASE 1. LEFT LUNG.

Large concentric, heavily pigmented mass of fibrous tissue in lower lateral portion of upper lobe. Concentric gray strands of fibrous tissue in this mass. Areas of nodular and diffuse pigmented fibrosis in remaining portion of lung with intervening areas of moderately emphysematous lung tissue. Markedly thickened pleura with scattered tags of fibrous tissue. Note contracted, irregular shape of lung.

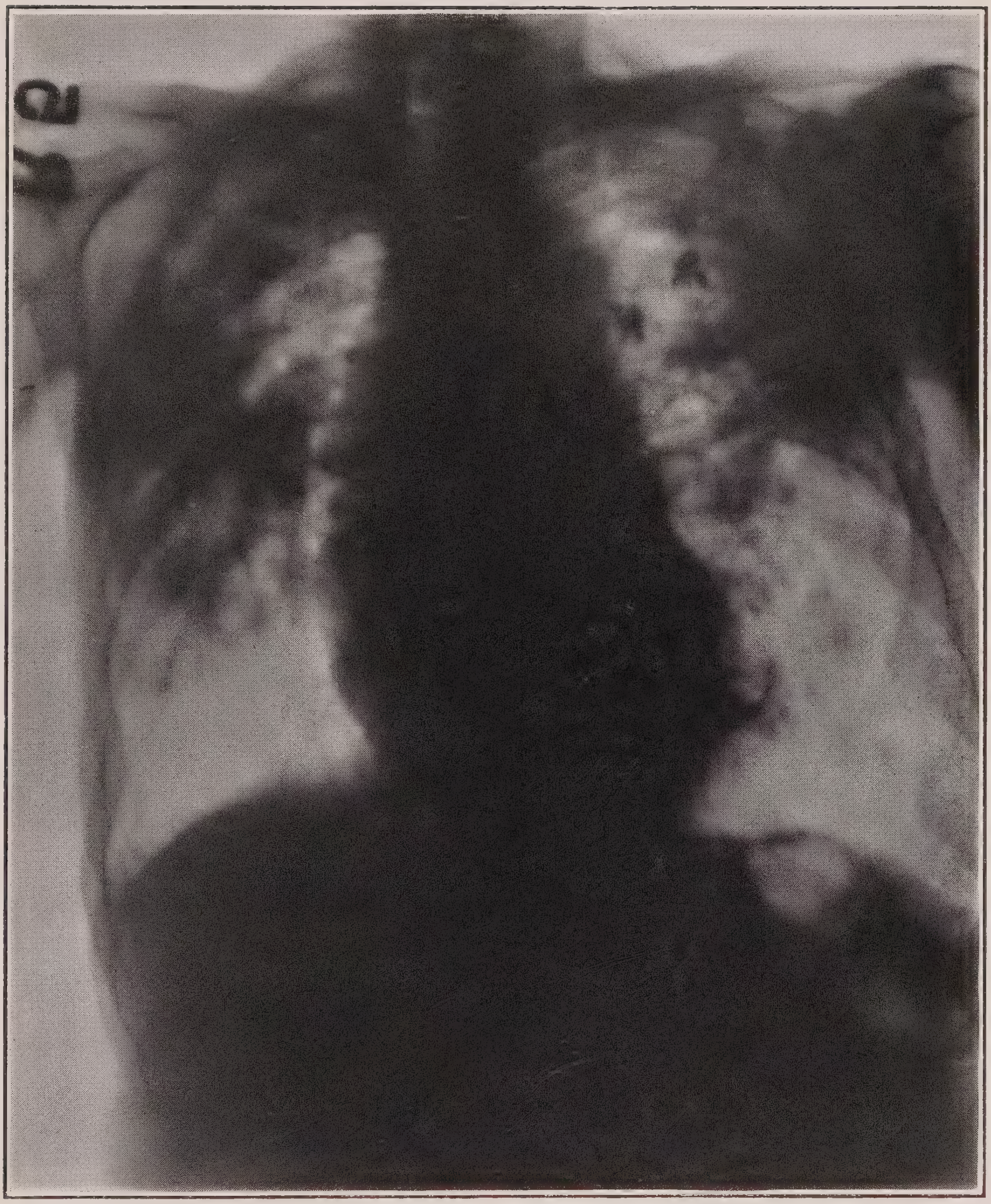


PLATE 38.—CASE 1. ANTE-MORTEM X-RAY.

Note areas of fibrous consolidation corresponding with those in the gross specimens (plates 36 and 37).
Diagnosis: Advanced anthraco-silicosis; cardiac enlargement. Total disability.

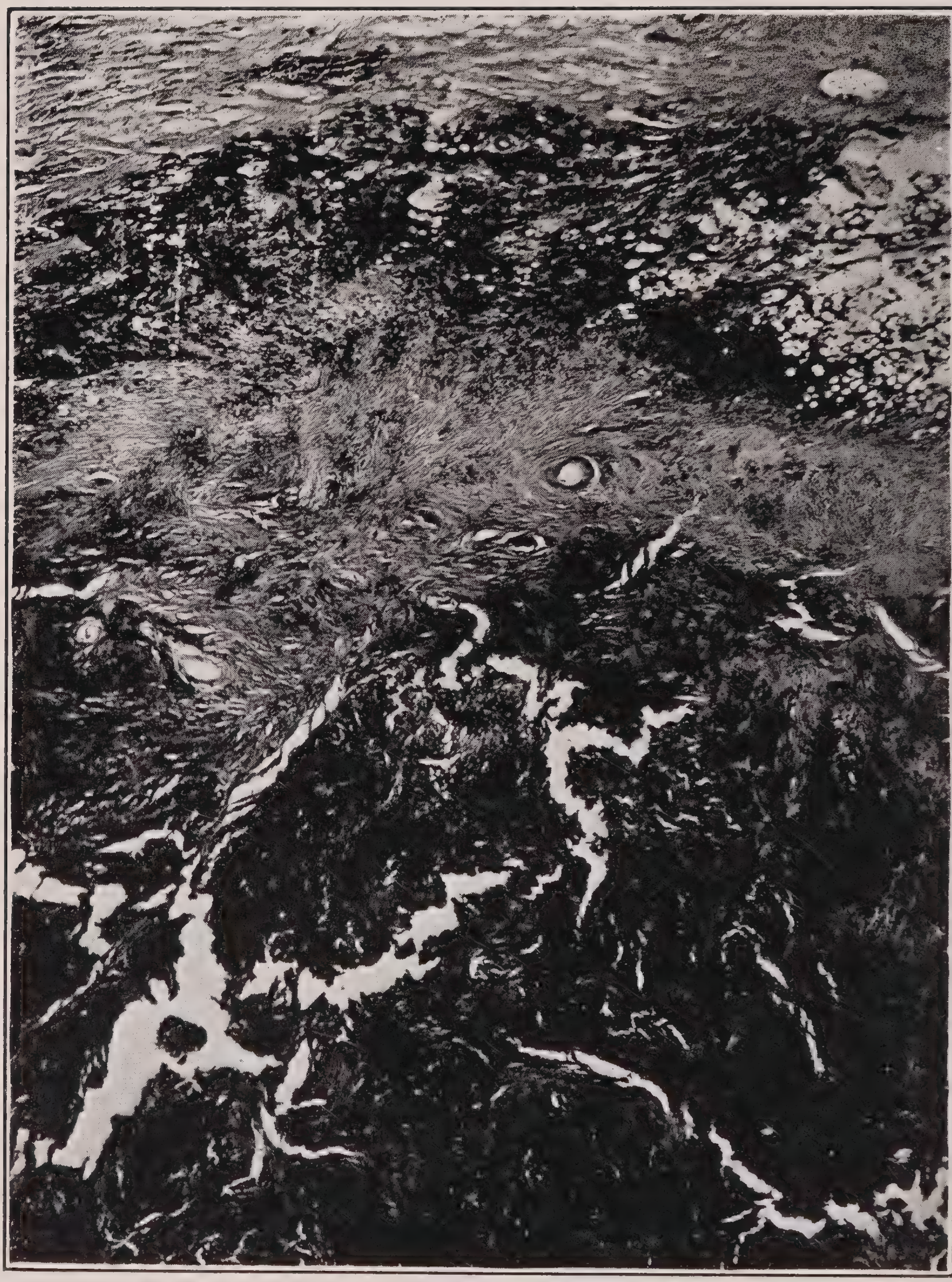


PLATE 39.—CASE 1.

Section of lung tissue showing portion of thickened pleura, underlying collection of coal dust, massive diffuse fibrosis with much engulfed coal dust, and interlacing strands of nonpigmented white fibrous tissue. Area of emphysema in upper left corner. (Magnification 16×.)

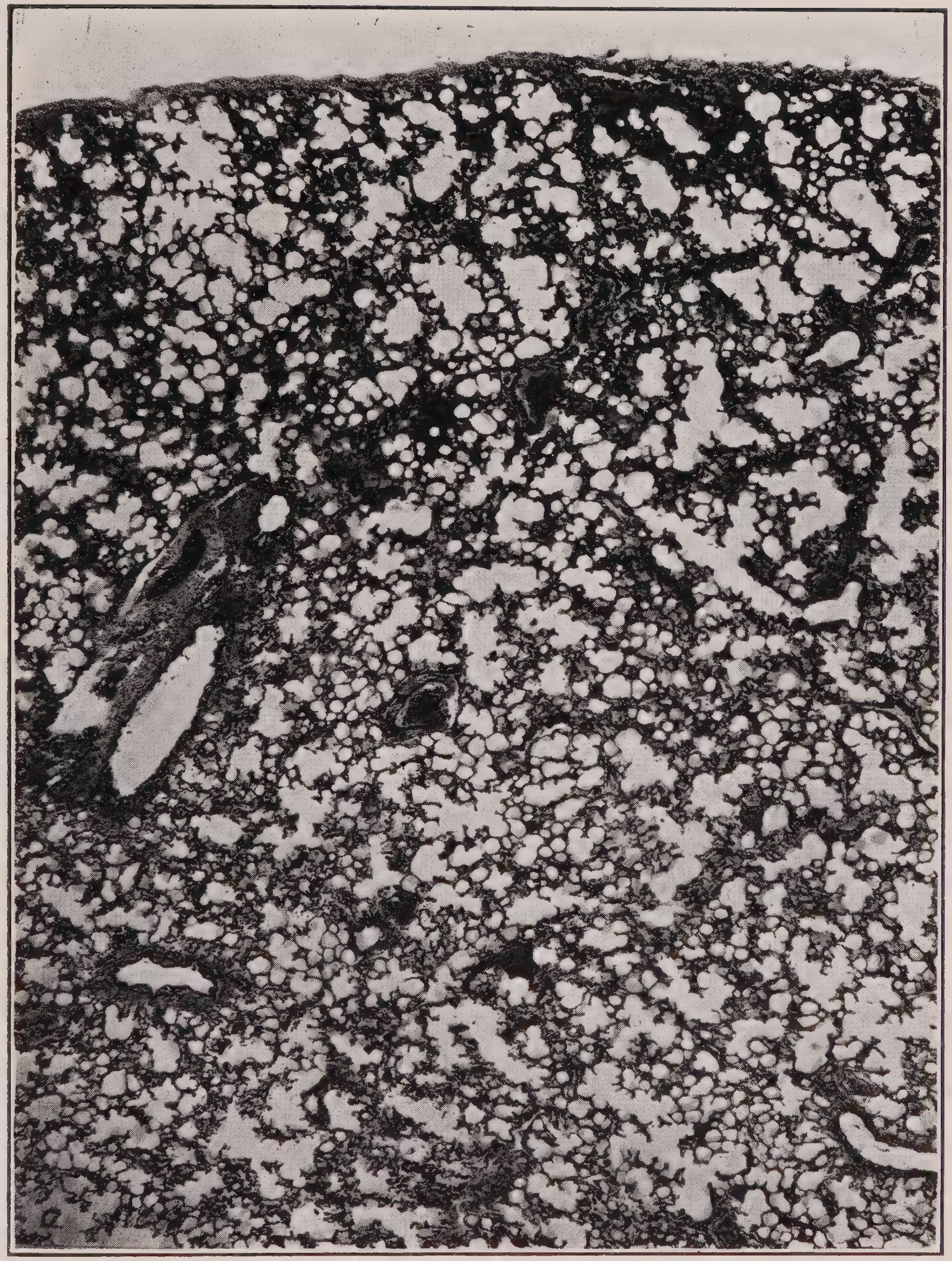


PLATE 40.

Section of practically normal human lung tissue for comparison with plate 39. (Magnification 16×).

PLATE 41.—CASE 2. RIGHT LUNG.

Upper and middle lobes are fused together. Lung tissue is practically obliterated by massive fibrosis. The central portion of the black pigmented mass is soft, noncaseous necrosis, about one-third of the involved area. A smaller firm mass in upper portion of middle lobe. Scattered diffuse and nodular, pigmented, fibrous masses in the remaining lung substance. An area of moderately emphysematous lung tissue is present at the apex. The lower lobe is almost completely composed of distended air sacs. Emphysema is marked in the middle lobe. Scattered fibrous tags occur at the apex and over the pleura.

PLATE 42.—CASE 2. LEFT LUNG.

Large indurated, fibrous mass, heavily pigmented, involving practically all the upper lobe. Central portion of this mass shows noncaseous necrosis and early cavitation. A smaller firm mass in upper portion of lower lobe. Numerous scattered nodular and diffuse pigmented fibrous masses, interspersed with emphysematous lung tissue throughout the remainder of the lung. Thickened walls of bronchi and blood vessels. A few scattered fibrous tags over pleura. Note distorted shape of lung.

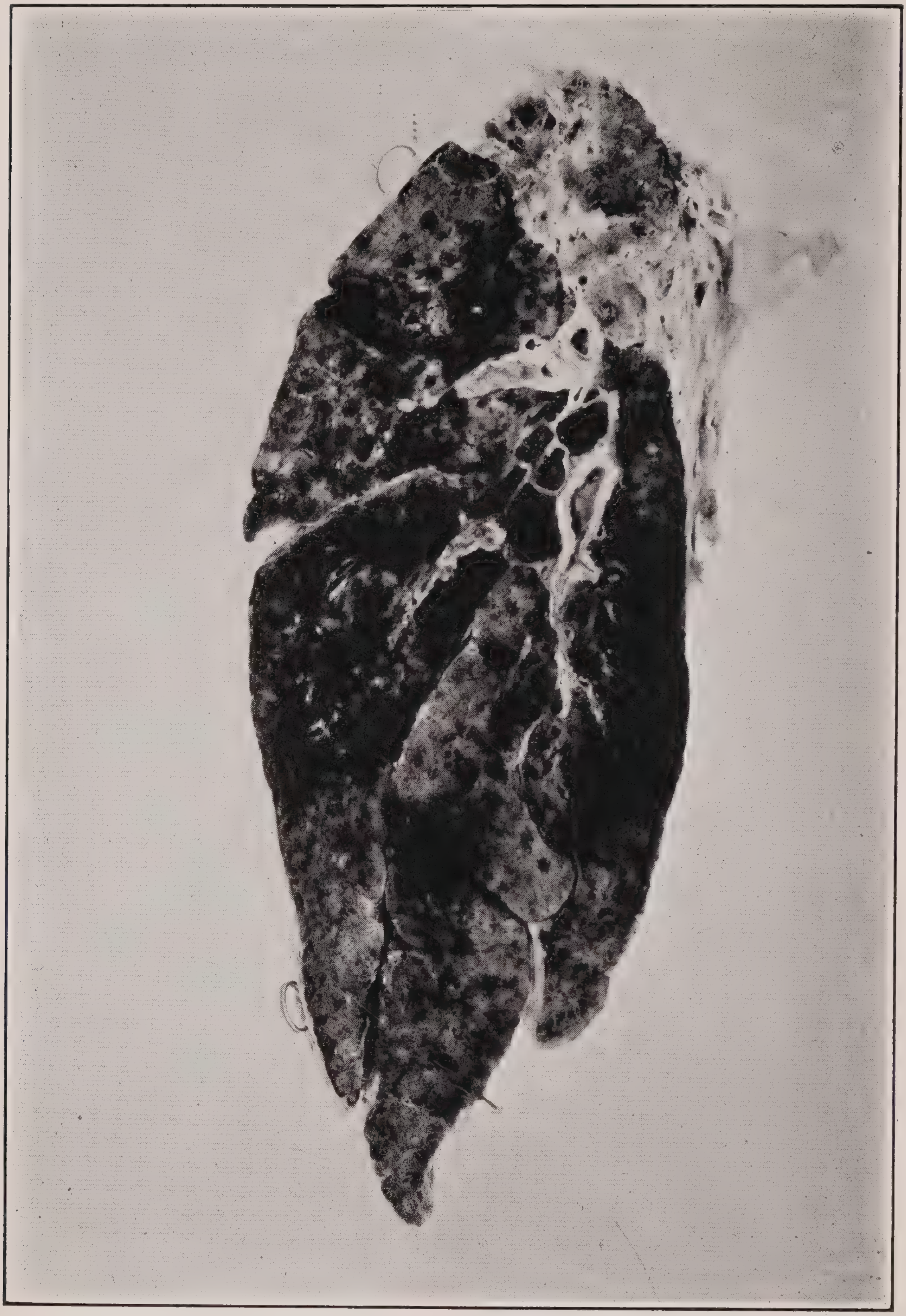


PLATE 43.—CASE 3. RIGHT LUNG.

Emphysematous and infarcted area at apex, separated from rest of lobe by dense fibrous connective tissue. Many scattered, black pigmented, nodular and diffuse fibrous masses throughout most of the lung. These are coalesced in upper portions of middle and lower lobes. Emphysema is moderate in the intervening lung tissue. A group of much distended air sacs is seen on medial margin of base. Heavily pigmented, enlarged, firm, hilar lymph glands. A few fine, scattered fibrous tags on pleura.

PLATE 44.—CASE 3. LEFT LUNG.

Many isolated and coalesced, black pigmented, indurated, fibrous tissue masses of varying sizes in middle and lower portions of upper lobe and upper portion of lower lobe. Emphysematous lung tissue at apex and base. A large group of distended air sacs on posterior margin of base. Very large, indurated, heavily pigmented hilar lymph glands.

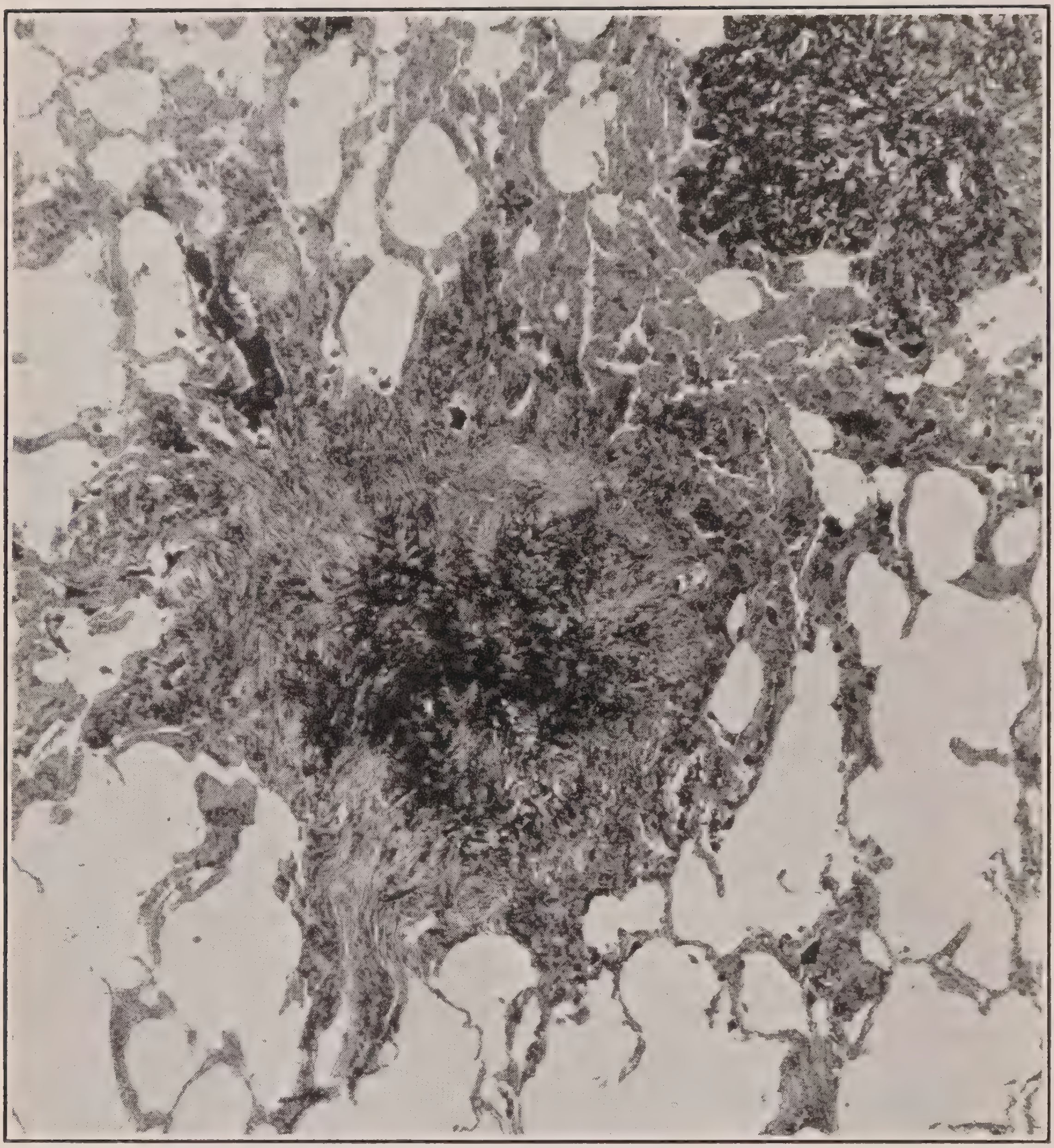


PLATE 45.—CASE 3.

Small, fibrous nodule with enclosed coal dust. Emphysema and congestion of adjacent lung tissue. (Magnification 80×.)

5. SELECTED CASE REPORTS

The findings in three cases are presented below.

CASE 1. M. S. AGE 68, AMERICAN, WHITE

Cause of death.—Cardiac decompensation.

Occupational history.—Began work at age of 9. Slate picker about 5 years. Inside laborer about 5 years. General farming in Pennsylvania, 24 years. Contract work, rock tunneling, 9 years. Contract miner, 16 years.

Medical history.—Continuous dyspnea, loss of weight, massive edema of lower extremities for 3 months prior to death, cough of 8 months' duration previous to death, slight hemoptysis on 3 occasions.

Physical findings.—Barrel-shaped chest with prominent intercostal, infra- and supra-clavicular spaces, heart greatly enlarged, valvular sounds indistinct and mixed, rate and rhythm very irregular, decreased resonance in both lung bases, numerous moist râles over entire chest.

Chemical examination of lung tissue.—Sample from solid portion of lung—ash 11.7 percent, silica 2.5 percent. Sample from remaining portion of lung—ash 5.2 percent, silica 1.0 percent. Average for entire lung—ash 8.5 percent, silica 1.8 percent. (Cf. plates 36, 37, 38, 39, and 40.)

CASE 2. W. H. AGE 65

Cause of death.—Anthraco-silicosis.

Occupational history.—Began work at age of 17. Plane rider, 6 years. Outside laborer, 15 years. Loader in mines, 1 year. Loader in rock tunnel, 1 year. Loader in mines, 2 years. Outside laborer, 10 years. Estimated time idle, 13 years. (The occupational history obtained was not specific as to the nature of the work performed during period as outside laborer, and no estimate of the total dust exposure can be made for this person.)

Medical history.—None obtainable.

Chemical analysis of lung tissue.—Ash 5.58 percent, silica 1.52 percent. (Cf. plates 41 and 42.)

CASE 3. G. V. AGE 59

Cause of death.—Spontaneous pneumothorax.

Occupational history.—Began work at age of 7. Slate picker in dry breaker, 4 years. Company laborer in mines, 42 years. Laborer in rock, anthracite mines, 4 years. Door boy, 2 years.

Medical history.—None obtainable. (Died suddenly.)

Chemical analysis of lung tissue.—Ash 10.4 percent, silica 1.2 percent. (Cf. plates 43, 44, and 45.)

VI. CORRELATION OF PHYSICAL FINDINGS WITH DUST EXPOSURE

On account of the importance of the quartz content of a given dust, the findings in regard to the proportion of free silica in the dusts encountered in the coal mines largely determined the grouping of the occupations to be studied. As previously stated, rock workers were found to be exposed to dust containing about 35 percent free silica, men in other nonmining occupations underground were exposed to dust of which about 13 percent was quartz, while coal miners and

breaker house employees worked in dust of which less than 5 percent was free silica. Men who had worked in atmospheres containing less than the specified minimum used for the purposes of statistical analysis i. e., 5 million dust particles per cubic foot of air, were used as a control group. No cases of anthraco-silicosis were found when the dust count was below this figure.

1. COMPOSITION OF THE OCCUPATIONAL GROUPS STUDIED

Men exposed to more than 5 million dust particles per cubic foot of air, less than 5 percent of which was free silica, were labeled group A. Miners and their helpers and breaker house employees largely composed this group. A subdivision (group B) consisted of those contract miners and their helpers who had spent most of their working time to date in the one occupation of mining hard coal. The men employed in the haulageways (chiefly maintenance and transportation workers) who were exposed to dust of which about 13 percent was free silica, were designated group C. Full-time rock workers (the number of whom was very small) and miners who had spent more than 2 or 3 years in rock work composed group D.

The number of men in the different groups considered were as follows:[18]

Total number examined	2, 711
Control group	361
Group A	1, 435
Group B (subdivision of group A)	426
Group C	602
Group D	151
Special groups [19]	162

2. PREVALENCE OF ANTHRACO-SILICOSIS ACCORDING TO MINE UNDER STUDY

The numbers quoted above represent totals for the three mines as a whole. The data were combined because differences in the prevalence rates of anthraco-silicosis according to mine were found to be small under similar amounts of dust exposure.

Men who had worked for more than 2 or 3 years in rock dust were not included in table 29, because the type of mining in each coal field necessitated a different proportion of the total force which was engaged in rock extraction. In mine no. 1 which represented the

[18] In the tables presented later showing number of men classified according to length of employment under given dust concentrations, the numbers do not check exactly with those given here, because in some instances exposures were so mixed as to make it necessary to omit certain workers from the classification according to length of employment under specific dust concentrations.

[19] Two in number: (1) Men who had had appreciable exposure to harmful dusts in other industries; and (2) anthracite coal mining employees who had changed more than 5 years before the date of examination, from very dusty to relatively nondusty occupations in the industry.

chamber and pillar type of mining, the miners and their helpers often had to take out top and bottom rock. In mine no. 2, however, the coal was extracted from highly pitched veins which necessitated little rockwork on the part of the miners themselves. Instead, a special crew of rock drillers was employed to penetrate the layers of rock so as to make the coal veins accessible. In mine no. 3 there was a combination of these two types of mining. Mine no. 1 was a dry mine, while nos. 2 and 3 were wet.

TABLE 29.—*Number and percentage of men examined having anthraco-silicosis in each of the three mines under study*[1]

Mine under study	Percentage of men having anthraco-silicosis in—		Number of men having anthraco-silicosis in—		Number of men examined
	Stage 1, 2, or 3	Stage 2 or 3	Stage 1, 2, or 3	Stage 2 or 3	
Mine no. 1	23.5	4.4	252	47	1,072
Mine no. 2	18.7	1.9	117	12	626
Mine no. 3	16.0	2.1	112	15	699

[1] Men who had worked for more than 2 or 3 years drilling rock, those who had had previous exposure to harmful dusts in other industries, and men who had changed more than 5 years previously from very dusty to relatively nondusty occupations in the anthracite industry were not included in this table.

The percentage of men having anthraco-silicosis, and the percentage in the second and third stage of the disease was somewhat higher in mine no. 1 than in either of the other two mines. Analysis according to billion particle-years of exposure,[20] however, disclosed the fact that the men in mine no. 1 had the greatest exposure to dust. Nearly 30 percent of the men in this mine had exposures in excess of 6 billion particles-years in contrast with 10 percent of the men in mine no. 2, and 18 percent of the men in mine no. 3. In view of these differences in the amount of exposure to dust, the variation in the prevalence rates shown in the first two columns of table 29 is not great enough to warrant separate analysis of the data for each coal field.

3. PREVALENCE OF ANTHRACO-SILICOSIS ACCORDING TO DURATION OF EXPOSURE TO DIFFERENT QUANTITIES AND KINDS OF DUST

A matter of primary interest is the length of time usually intervening between the beginning of exposure and the onset of disease. Among the 500 men in group A who had been exposed to dust for less than 15 years, only 7 cases of anthraco-silicosis were found. The proportion of men having the disease ranged from none to 1.8 percent under different concentrations, but did not exceed the latter percentage

[20] The number of billion particle-years of exposure was computed for the purpose of combining the factors of length of time employed in anthracite coal mining, and the amount of dust to which the worker was exposed. It was obtained by multiplying the average number of dust particles per cubic foot of air by the number of years the employee worked in such dust. The product appears to constitute a fair estimate of the total exposure to anthracite coal-mining dusts.

139428—35——6

even when the dust count was greater than 300 million particles per cubic foot of air. There were no cases of anthraco-silicosis among the 93 men in group B whose length of service was less than 15 years, and in group C there was only one case among the 327 men having this length of service. The eight cases mentioned above were all in the first stage of the disease. An important characteristic, therefore, is the slow development of lung pathology regardless of the intensity of exposure.

Among rockworkers, however, cases developed more rapidly; about 13 percent of the men who had worked in rock dust for more than 2 or 3 years during employment in the industry totaling less than 15 years, were found in stage 1 anthraco-silicosis.

TABLE 30.—*Number and percentage of men having anthraco-silicosis in each of four groups of anthracite coal-mining employees, classified according to their average dust exposure and by number of years in the industry*

Group	5–99 million dust particles per cubic foot of air, for—			100–199 million dust particles per cubic foot of air, for—			200–299 million dust particles per cubic foot of air, for—			300 or more million dust particles per cubic foot of air, for—		
	Less than 15 years	15–24 years	25 or more years	Less than 15 years	15–24 years	25 or more years	Less than 15 years	15–24 years	25 or more years	Less than 15 years	15–24 years	25 or more years
PERCENTAGE HAVING ANTHRACO-SILICOSIS (STAGE 1, 2, OR 3)												
A	1.1	1.5	7.4	1.8	14.1	54.0	0	28.9	71.1	1.7	58.1	88.8
B	--------	--------	(1)	--------	21.4	68.7	(1)	29.7	75.0	0	63.5	94.4
C	0.4	3.1	23.3	0	0	26.3	(1)	(1)	--------	--------	--------	(1)
D	(1)	(1)	(1)	12.5	(1)	(1)	23.5	71.4	(1)	8.8	56.2	92.0
PERCENTAGE HAVING STAGE 2 OR 3 ANTHRACO-SILICOSIS												
A	0	0	0	0	0	6.2	0	1.1	12.4	0	5.4	27.0
B	--------	--------	(1)	--------	0	9.4	(1)	0	11.4	0	7.0	27.8
C	0	0	0	0	0	0	(1)	(1)	--------	--------	--------	(1)
D	(1)	(1)	(1)	0	(1)	(1)	0	7.1	(1)	0	0	40.0
NUMBER OF MEN HAVING ANTHRACO-SILICOSIS (STAGE 1, 2, OR 3)												
A	1	1	4	1	12	61	0	26	69	5	108	135
B	--------	--------	1	--------	3	22	0	11	33	0	73	85
C	1	2	24	0	0	5	0	0	--------	--------	--------	0
D	0	0	0	2	6	2	4	10	7	3	9	23
NUMBER OF MEN HAVING STAGE 2 OR 3 ANTHRACO-SILICOSIS												
A	0	0	0	0	0	7	0	1	12	0	10	41
B	--------	--------	--------	--------	0	3	0	0	5	0	8	25
C	0	0	0	0	0	0	0	0	--------	--------	--------	0
D	0	0	0	0	2	1	0	1	1	0	0	10
NUMBER OF MEN EXAMINED												
A	95	66	54	56	85	113	63	90	97	286	186	152
B	0	0	1	0	14	32	8	37	44	85	115	90
C	282	65	103	37	23	19	8	2	0	0	0	1
D	4	1	1	16	9	2	17	14	8	34	16	25

1 Less than 10 men examined.

A. All employees except those in nonmining occupations underground and those who had worked in rock dust for more than 2 or 3 years.
B. Contract miners and their helpers who had done little rock work (subdivision of group A).
C. Men in nonmining occupations underground, except rock workers.
D. Men who had worked in rock dust for more than 2 or 3 years.

When employment extended from 15 to 24 years, the prevalence of the disease was much greater. In the occupations involving exposure to dust containing less than 5 percent free silica (group A), about 14 percent of the men had anthraco-silicosis when the dust concentration was 100 to 199 million particles per cubic foot, 29 percent when the dust concentration was 200 to 299 million particles, and 58 percent when the dust count exceeded 300 million particles.

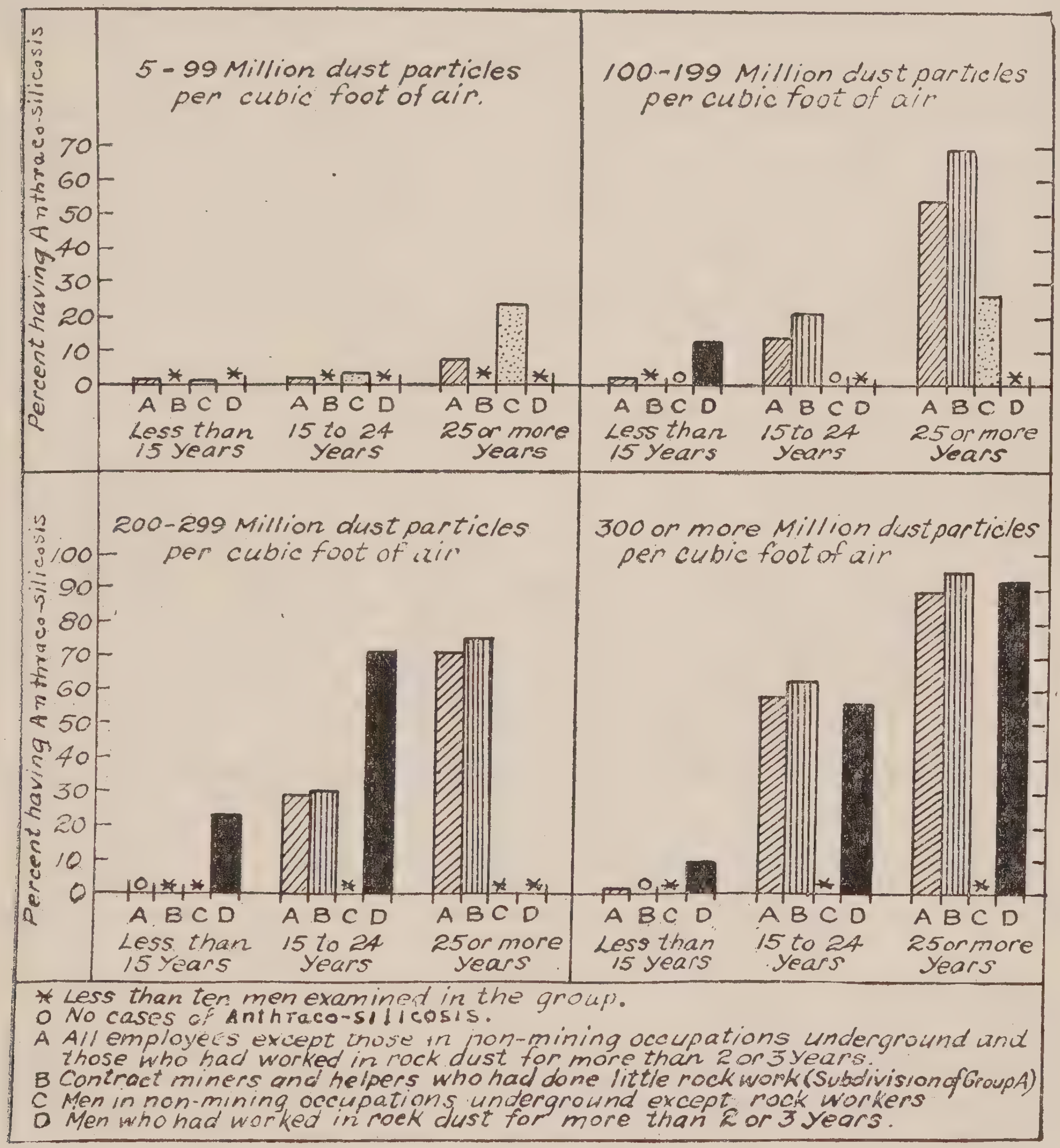


Figure 18. Percentage of men having anthraco-silicosis (stage 1, 2, or 3) in each of the four groups of anthracite coal mining employees, classified according to dust exposure and length of time in the industry.

About 5 percent of the last-named group of men was found in the more advanced stages of the disease. Of the 40 rockworkers (men who had worked for more than 2 or 3 years in rock dust), whose period of service in the industry was 15 to 24 years, 25, or 63 percent were diagnosed as cases of anthraco-silicosis. Of the 25, 3 had progressed beyond stage 1.

When the period of employment exceeded 25 years the prevalence rates were still higher. In group A the rate rose from 7.4 percent in a

dust concentration below 100 million particles to 54 percent when the dust count was 100 to 199 million particles, to 71 percent when the exposure was from 200 to 299 million particles, and to 89 percent under dust concentrations in excess of 300 million particles per cubic foot. No advanced cases were found in group A when the exposure was less than 100 million particles. However, between the limits of 100 and 199 million particles, 6 percent had stage 2 or 3 anthraco-silicosis after more than 25 years' service, 12 percent when the dust count was 200 to 299 million particles, and 27 percent when there were more than 300 million dust particles to the cubic foot.

Among persons employed for more than 25 years in the nonmining occupations underground (rock workers excepted), about one-fourth showed evidence of anthraco-silicosis. None of these cases, however, had progressed beyond stage 1. Most of the men in this group

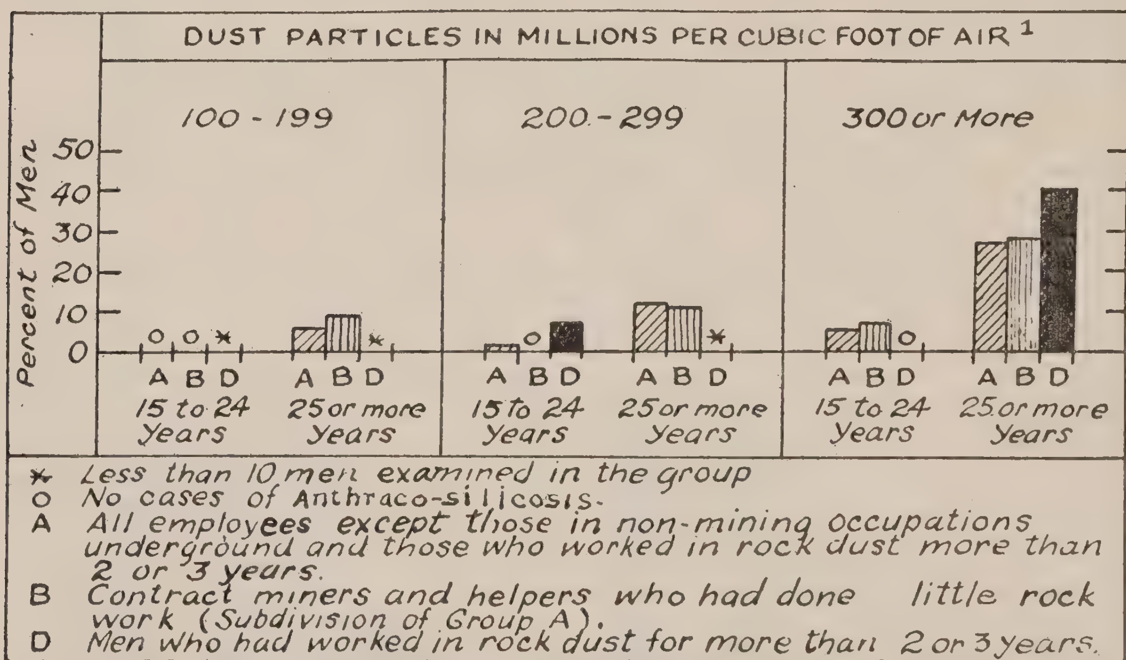


Figure 19. Percentage of men having stage 2 or 3 anthraco-silicosis according to dust count and number of years in the industry: Groups A, B, and D compared.

[1] There were no cases in stage 2 or 3 among men in the industry less than 15 years, and no cases of this severity among persons exposed to less than 100 million dust particles per cubic foot of air.

(group C) worked in atmospheres containing less than 200 million dust particles per cubic foot, the quartz content of the dust being about 13 percent as previously stated.

About 9 out of 10 men who had worked for more than 2 or 3 years in rock dust, and who had remained in the hard-coal mining industry more than 25 years, had anthraco-silicosis. Among those exposed for this length of time to more than 300 million particles per cubic foot, 40 percent were diagnosed as having the disease in its second or third stage.

Nearly all the regular miners and mine laborers who had worked where the dust count exceeded 300 million particles had anthraco-silicosis after more than 25 years employment. The miners and mine laborers who had remained continuously in work at the coal face

generally fared worse than the group which shifted occasionally from mining to nonmining jobs in the industry.

4. ANTHRACO-SILICOSIS IN GROUP C, BY MINES

Under the relatively low dust counts recorded for men in the nonmining occupations underground (with the exception of rock workers), surprisingly high prevalence rates of anthraco-silicosis were found. As shown in table 30, almost one-fourth of the group C men who had worked for 25 or more years in atmospheres containing less than 100 million dust particles to the cubic foot of air were diagnosed as having stage 1 anthraco-silicosis in contrast with only 7 percent of the men in group A who had worked the same length of time in similar quantities of dust.

In the haulageways where most of the men in group C are employed, the air contains not only the dusts arising from both coal and rock drilling operations, but also sand used on the rails to obtain traction. Sand is almost entirely pure quartz.

The haulageways of mine no. 1 were observed to be dustier than those in the other two mines, principally because it was a dry mine while the other two were wet. For this reason the proportion of men in group C having anthraco-silicosis is presented separately for each of the mines. From table 31 it may be seen that 33 percent of the men employed in the haulageways of mine no. 1 developed anthraco-silicosis after 25 or more years service in contrast with 10 percent of the men in mine no. 2, and 4 percent in mine no. 3.

TABLE 31.—*Number and percentage of men having anthraco-silicosis in group C after 25 or more years employment in atmospheres containing 5 to 199 million dust particles per cubic foot of air, by mines*

Mine	25 or more years employment in air containing 5 to 199 million dust particles per cubic foot		
	Percentage having anthraco-silicosis	Number having anthraco-silicosis	Number of men examined
All 3 mines	23.8	29	122
Mine no. 1	32.9	26	79
Mine no. 2	10.0	2	20
Mine no. 3	4.3	1	23

5. AGE DISTRIBUTION OF THE GROUPS UNDER CONSIDERATION

Since age is an important factor in the development of many diseases, it is essential that the age distribution of the different groups of workers should be considered. Less than 1 percent of the coal mining employees below age 35 were found with anthraco-

silicosis; hence the age comparisons were confined to persons 35 or more years old. There was not much difference in the age distribution of the groups under observation. As one might expect, the group composed solely of miners and their helpers (group B) had a larger proportion of men at ages 35 to 44 than was found in the three other groups. The rock workers had the highest proportion of men at the younger ages, but in spite of this favorable factor, a larger proportion had anthraco-silicosis than was found in any other group.

TABLE 32.—*Age distribution of men, age 35 and over in each of 4 groups of anthracite coal mining employees*

Age group	Percentage of men at specified ages in group—				Number of men at specified ages in group—			
	A	B	C	D	A	B	C	D
Age 35 and over	100.0	100.0	100.0	100.0	1,066	362	257	109
35 to 44	49.3	42.8	49.0	56.0	525	155	126	61
45 to 54	36.6	42.6	33.9	33.0	390	154	87	36
55 to 64	11.6	13.5	15.2	10.1	124	49	39	11
65 and over	2.5	1.1	1.9	.9	27	4	5	1

A. All employees except those in nonmining occupations underground, those who had worked in rock dust for more than 2 or 3 years, men who had had appreciable exposure to harmful dusts in other industries, and those who had changed from very dusty to relatively nondusty occupations in the industry more than 5 years prior to the date of examination.
B. Contract miners and their helpers who had done little rock work (subdivision of group A).
C. Men in nonmining occupations underground except rock workers.
D. Men who had worked in rock dust for more than 2 or 3 years.

6. PREVALENCE OF ANTHRACO-SILICOSIS AT DIFFERENT AGES

Prevalence rates were computed according to age in group A because it afforded the largest number of men exposed to dust of a given free silica content (less than 5 percent free silica). After more than 25 years employment in the heaviest dust concentrations, the proportion of group A men having the disease at ages 35 to 44 was 87 percent; at ages 45 to 54, 89 percent; and at ages 55 and over, 90 percent. Thus approximately 9 out of 10 men exposed to dust containing less than 5 percent free silica developed anthraco-silicosis after more than 25 years' work in atmospheres containing 300 million or more dust particles per cubic foot, regardless of age. The percentage of persons in the more advanced stages of the disease was 17 at ages 35 to 44, 27 at ages 45 to

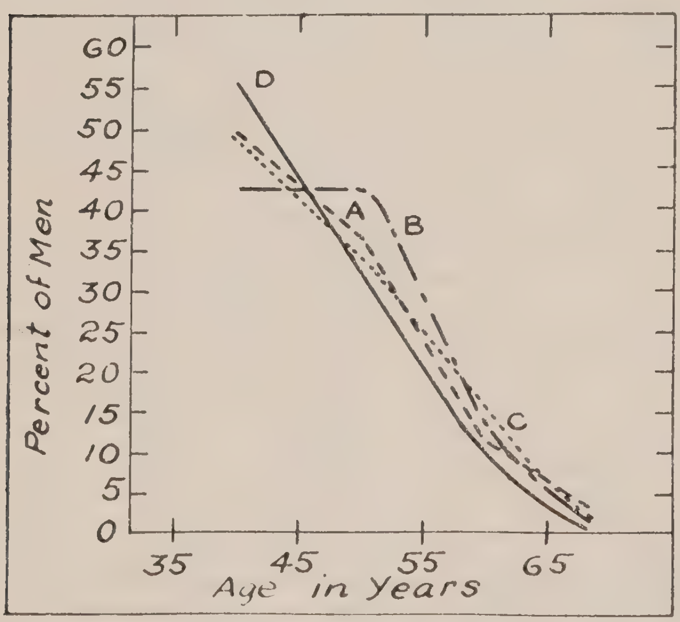


FIGURE 20.—Age distribution of men age 35 and over in each of 4 groups of the anthracite coal mining employees.

54, and 35 at ages 55 and over, when the term of service was more than 25 years, and the dust count in excess of 300 million particles. The higher incidence in the upper age groups probably is due in part to the fact that some of these men had worked more than 35 years while such long exposures are obviously impossible for the younger men.

Under lower dust concentrations the effect of age was more discernible. Exposure for more than 25 years to 100–199 million dust particles per cubic foot caused anthraco-silicosis among 28 percent of the group A men at ages 35 to 44, 59 percent at ages 45 to 54, and 76 percent at ages 55 and over. A more pronounced increase in prevalence with advance in age may be noted under exposure to 200–299 million dust particles per cubic foot. Only under the heaviest dust concentrations encountered does the age factor appear to be completely submerged.

TABLE 33.—*Number and percentage of men having anthraco-silicosis in group A, by age*

Average dust exposure [1]	Percentage of men having anthraco-silicosis						Number of men examined and number having anthraco-silicosis								
	Stage 1, 2, or 3			Stage 2 or 3			All periods in the industry			15–24 years in the industry			25 years or more in the industry		
	All periods in the industry	15–24 years	25 years or more	All periods in the industry	15–24 years	25 years or more	Number of men	Number of cases: Stage 1, 2, or 3	Number of cases: Stage 2 or 3	Number of men	Number of cases: Stage 1, 2, or 3	Number of cases: Stage 2 or 3	Number of men	Number of cases: Stage 1, 2 or 3	Number of cases: Stage 2 or 3
ALL AGES															
5–99	2.8	1.5	7.4	0	0	0	215	6	0	66	1	0	54	4	0
100–199	29.1	14.1	54.0	2.8	0	6.2	254	74	7	85	12	0	113	61	7
200–299	38.0	28.9	71.1	5.2	1.1	12.4	250	95	13	90	26	1	97	69	12
300+	39.7	58.0	88.8	8.2	5.4	27.0	624	248	51	186	108	10	152	135	41
35–44 YEARS OF AGE															
5–99	1.8	3.2	0	0	0	0	57	1	0	31	1	0	12	0	0
100–199	17.0	13.5	27.6	0	0	0	94	16	0	52	7	0	29	8	0
200–299	21.3	25.4	29.4	0	0	0	89	19	0	55	14	0	17	5	0
300+	43.4	55.1	86.7	5.0	5.1	16.7	219	95	11	118	65	6	30	26	5
45–54 YEARS OF AGE															
5–99	7.1	(2)	5.6	0	(2)	0	28	2	0	8	0	0	18	1	0
100–199	52.5	33.3	58.7	1.3	0	1.6	80	42	1	15	5	0	63	37	1
200–299	62.1	40.7	74.1	6.9	3.7	8.6	87	54	6	27	11	1	58	43	5
300+	76.6	77.8	89.0	18.4	8.9	26.8	141	108	26	45	35	4	82	73	22
55 YEARS AND OVER															
5–99	12.0	------	12.5	0	-----	0	25	3	0	0	0	0	24	3	0
100–199	72.7	(2)	76.2	27.3	(2)	28.6	22	16	6	1	0	0	21	16	6
200–299	95.5	------	95.5	31.8	-----	31.8	22	21	7	0	----	----	22	21	7
300+	87.2	(2)	90.0	29.8	(2)	35.0	47	41	14	5	4	0	40	36	14

[1] In millions of particles per cubic foot of air. [2] Less than 10 men examined.

7. THRESHOLD DOSAGE

For the purpose of determining safe limits of dust exposure, the groups working in atmospheres containing less than 100 million particles were subdivided. The number of men exposed to relatively small quantities of dust containing less than 5 percent free silica was too small to afford reliable information for determining the quantity of dust which could be tolerated with no adverse effect on health. However, from the data available, it appeared reasonable to assume that employment in an atmosphere containing less than 50 million dust particles per cubic foot would be associated with a negligible number of cases of anthraco-silicosis when the quartz content of the dust was less than 5 percent. (Cf. table 34.)

TABLE 34.—*Extent to which anthraco-silicosis developed under exposure to the smaller as compared with the larger quantities of dust in each of 4 groups of hard-coal mining operatives in Pennsylvania*

Dust count in millions of particles per cubic foot	All ages and periods of service in group—				Below age 45				Age 45 or above							
					More than 15 years' service in group—[1]				15 to 24 years' service in group—[1]				25 or more years' service in group—			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
PERCENTAGE HAVING ANTHRACO-SILICOSIS (STAGE 1, 2, OR 3)																
5–34	1.3	-----	7.3	[2]	0	-----	0	-----	[2]	-----	[2]	-----	3.3	-----	29.1	-----
35–64	5.3	-----	7.0	-----	[2]	-----	4.8	-----	[2]	-----	[2]	-----	[2]	-----	25.0	-----
65–99	7.5	[2]	4.0	[2]	5.6	-----	7.1	[2]	[2]	-----	[2]	[2]	[2]	[2]	28.6	-----
100–199	*29.1*	*54.3*	6.3	*37.1*	15.3	23.5	3.2	[2]	27.8	[2]	[2]	[2]	*63.1*	*76.9*	[2]	[2]
200–299	*38.4*	*49.4*	[2]	*53.8*	25.0	36.7	[2]	61.5	*40.7*	27.3	-----	[2]	*80.0*	*75.0*	-----	[2]
300+	*39.7*	*54.5*	[2]	*46.7*	*57.2*	*60.2*	[2]	*64.7*	*78.0*	*80.0*	-----	[2]	*89.3*	*93.9*	-----	*90.5*
NUMBER HAVING ANTHRACO-SILICOSIS (STAGE 1, 2, OR 3)																
5–34	2	-----	16	0	0	-----	0	-----	0	-----	0	-----	1	-----	16	-----
35–64	1	-----	4	-----	0	-----	1	-----	0	-----	0	-----	1	-----	3	-----
65–99	3	1	7	0	1	-----	1	0	0	-----	1	0	2	1	4	-----
100–199	*74*	*25*	5	*10*	15	4	1	*6*	5	1	0	*1*	*53*	*20*	4	*1*
200–299	*96*	*44*	0	*21*	20	11	0	8	*11*	3	-----	*4*	*64*	*30*	-----	*5*
300+	*248*	*158*	0	*35*	*95*	*53*	0	*11*	*39*	*28*	-----	2	*109*	*77*	-----	*19*
NUMBER OF MEN EXAMINED																
5–34	156	0	219	1	46	0	38	0	5	0	9	0	30	0	55	0
35–64	19	0	57	0	6	0	21	0	1	0	1	0	7	0	12	0
65–99	40	1	174	5	18	0	14	1	2	0	4	1	5	1	14	0
100–199	*254*	*46*	79	*27*	98	17	31	*9*	16	3	2	*1*	*84*	*26*	9	*1*
200–299	*250*	*89*	10	*39*	80	30	2	13	*27*	11	0	*4*	*80*	*40*	0	*5*
300+	*624*	*290*	1	*75*	*166*	*88*	1	*17*	*50*	*35*	0	3	*122*	*82*	0	*21*

[1] Only 2 cases of anthraco-silicosis were found among men exposed for less than 15 years to a dust concentration below 100,000,000 particles per cubic feet. One case was in group A and the other in group C.
[2] Less than 10 or 11 men examined in the group.

A. All employees except those in nonmining occupations underground and those who worked in rock dust for more than 2 or 3 years. Two special groups mentioned in footnote 19, page 74, are also excluded.
B. Contract miners and their helpers who had done little rock work (subdivision of group A).
C. Men in nonmining occupations underground except rock workers.
D. Men who had worked in rock dust for more than 2 or 3 years.

NOTE.—The *italics* indicate the groups in which stage 2 or 3 anthraco-silicosis was encountered.

When free silica constituted about 13 percent of the dust, as was found in the gangways exclusive of places in which rock-drilling operations were being carried on, lower concentrations of dust produced anthraco-silicosis. About one-fourth of the men engaged in work underground other than that at the coal face and at rock drilling or loading were found in stage 1 anthraco-silicosis when the age was above 45 and work had continued for more than 25 years in air containing 5 to 34 million dust particles. However, only four cases of the disease were encountered in this group of men when the dust count was less than 15 million particles. A safe limit in the gangways when the dust contains about 13 percent free silica might be set tentatively at 10 to 15 million particles per cubic foot. The limit of toleration for rock workers would be somewhat lower, since the quartz content of the rock dust liberated in the hard-coal mines was found to be about 35 percent. It appears that a safe limit for rock workers is from 5 to 10 million dust particles per cubic foot of air. This estimate is based largely on the results among men in the haulageways exposed to dust containing 13 percent free silica, exclusive of rock workers, because it could not be determined from the experience of the rock workers themselves, as none was employed in such low concentrations. This estimate checks fairly well with the findings for the granite-cutting industry of Barre where the average quartz content of the dust is about the same as in rockwork in the anthracite mines studied, namely, about 35 percent. The limits of dustiness regarded as reasonably safe in the Barre cutting sheds were placed at approximately 10 million particles (*11*).

8. PROGRESS OF PULMONARY CHANGES

It is obviously impossible to determine from one examination of an individual the rapidity with which pulmonary changes are taking place. A clue as to probable tendencies may be obtained, however, from the history of cases. A review of the case records of 59 workers who had been exposed to heavy concentrations of dust but who had been transferred to less dusty occupations at least 5 years prior to the date of examination indicated that under such conditions the pulmonary changes may have been retarded but had not become entirely arrested.

From the histories obtained on a group of 135 totally disabled men, it was found that several in this group had worked at less dusty and less arduous tasks after the development of their disability, but the respiratory embarrassment had not been relieved, and it continued to progress to such an extent as to render the patients incapable of following any gainful occupation.

9. PULMONARY INFECTION WITH OR WITHOUT ANTHRACO-SILICOSIS

The extent of pulmonary infection, including clinical tuberculosis, was ascertained in eight different groups of anthracite coal mining employees. The last group shown in tables 35 and 36, viz: "All others exposed to 100 or more million particles" was composed largely of men whose major occupation was mining but who had changed from time to time to other jobs in the industry. It also includes breaker-house employees and certain other occupations which involved exposure to coal dust containing less than 5 percent free silica. This group is of interest for comparison with the miners who remained continuously, or virtually so, in the occupation of mining, i. e., the group designated "Regular miners" in tables 35 to 38 and 41 to 43.

The number of men in each of the eight groups, classified according to age, is shown in table 35. The number and percentage of these men having pulmonary infection are recorded in table 36.

TABLE 35.—*Number of men examined in each specified group of workers, by age*

Groups of anthracite coal mining employees	All adult ages	Adult ages below 35	35 to 44	45 to 54	55 to 64	65 and over
All men examined	2,711	1,002	829	605	224	51
Control group [1]	361	168	90	64	24	15
Group C (in haulageways) [2]	602	327	127	94	48	6
Group D (rock workers)	151	39	61	36	14	1
Group B (regular miners) [3]	426	64	155	154	49	4
Previous exposure to other dusts [4]	103	9	47	33	11	3
Special group [5]	59	1	6	23	17	12
All others exposed to 5–99 million particles [6]	247	117	68	31	23	8
All others exposed to 100+million particles [6]	762	277	275	170	38	2

[1] Men having dust exposure which averaged less than 5 million particles per cubic foot of air.
[2] Men in nonmining occupations underground, except rock workers, whose average exposure was more than 5 million dust particles per cubic foot of air.
[3] Contract miners and their helpers who had done little rock work and who had spent most of their working time to date in the occupation of mining hard coal.
[4] Men who had had appreciable exposure to harmful dusts in other industries.
[5] Men who had changed more than 5 years prior to the date of examination from very dusty to relatively nondusty occupations in the anthracite industry.
[6] Part of group A (men exposed to dust containing less than 5 percent free silica).

In the control group about 7 percent showed evidence of pulmonary infection. This proportion may be compared with 14 percent among the men in nonmining occupations underground, exclusive of rock workers, with 37 percent among the rock workers, and with 42 percent of the regular miners. The lower prevalence of pulmonary infection among rock workers than among regular miners is probably due to the fact that the former group contained a larger proportion of younger men, as shown in figure 20. At ages 35 to 54 the prevalence of pulmonary infection was greater among rock workers than among the regular miners.

TABLE 36.—*Number and percentage of men in each specified group of anthracite coal mining employees having pulmonary infection, and number and percentage having clinical pulmonary tuberculosis, by age*

Groups of anthracite coal mining employees	Percentage of men examined having infection specified						Number of men examined having infection specified					
	Age group						Age group					
	All adult ages	Adult ages below 35	35–44	45–54	55–64	65 and over	All adult ages	Adult ages below 35	35–44	45–54	55–64	65 and over
PULMONARY INFECTION, INCLUDING CLINICAL PULMONARY TUBERCULOSIS												
All men examined	23.9	6.1	25.9	38.5	53.6	37.3	648	61	215	233	120	19
Control group [1]	7.2	2.4	10.0	14.1	12.5	6.7	26	4	9	9	3	1
Group C (in haulageways) [2]	14.1	4.3	14.2	30.9	41.7	(6)	85	14	18	29	20	4
Group D (rock workers)	37.1	0	41.0	58.3	71.4	(6)	56	0	25	21	10	0
Group B (regular miners) [3]	42.0	17.2	38.1	45.5	73.5	(6)	179	11	59	70	36	3
Previous exposure to other dusts [4]	30.1	(6)	21.3	36.4	54.5	(6)	31	2	10	12	6	1
Special group [5]	47.5	(6)	(6)	43.5	52.9	50.0	28	0	3	10	9	6
All others exposed to 5–99 million particles [7]	12.6	2.6	13.2	25.8	34.8	(6)	31	3	9	8	8	3
All others exposed to 100+million particles [7]	27.8	9.7	29.8	43.5	73.7	(6)	212	27	82	74	28	1
CLINICAL PULMONARY TUBERCULOSIS												
All men examined	6.1	1.0	5.3	10.1	20.1	11.8	166	10	44	61	45	6
Control group [1]	.8	0	1.1	1.6	0	6.7	3	0	1	1	0	1
Group C (in haulageways) [2]	4.3	.3	2.4	13.8	16.7	(6)	26	1	3	13	8	1
Group D (rock workers)	19.2	0	19.7	25.0	57.1	(6)	29	0	12	9	8	0
Group B (regular miners) [3]	7.7	1.6	5.8	8.4	20.4	(6)	33	1	9	13	10	0
Previous exposure to other dusts [4]	9.7	(6)	4.3	9.1	36.4	(6)	10	1	2	3	4	0
Special group [5]	15.3	(6)	(6)	13.0	17.6	16.7	9	0	1	3	3	2
All others exposed to 5–99 million particles [7]	3.6	.9	1.5	6.5	13.0	(6)	9	1	1	2	3	2
All others exposed to 100+million particles [7]	6.2	2.2	5.5	10.0	23.7	(6)	47	6	15	17	9	0

[1] Men whose dust exposure averaged less than 5 million particles per cubic foot.
[2] Men in nonmining occupations underground, except rock workers, whose average exposure was more than 5 million dust particles per cubic foot of air.
[3] Contract miners and their helpers who had done little rock work and who had spent most of their working time to date in the occupation of mining hard coal.
[4] Men who had had appreciable exposure to harmful dusts in other industries.
[5] Men who had changed more than 5 years previously from very dusty to relatively nondusty occupations in the anthracite industry.
[6] Less than 10 men examined in the group specified.
[7] Part of group A (men exposed to dust containing less than 5 percent free silica).

PREVALENCE OF CLINICAL PULMONARY TUBERCULOSIS

Several surveys have shown that tuberculosis of the lungs occurs among 1 to 2½ percent of the general adult white male population of the country. In a study of tuberculosis in Framingham, Mass., it was found that about 1 percent were suffering from the disease in an active form, and another 1 percent were classified as having arrested tuberculosis (*19*). Physical examination of 100,924 adult white males made by the Life Extension Institute indicated a prevalence rate of about 1½ percent when suspected cases were included (*20*). A somewhat higher percentage, namely, 2½ percent, was found by the Public Health Service from the examination of 10,000 male industrial workers (*21*).

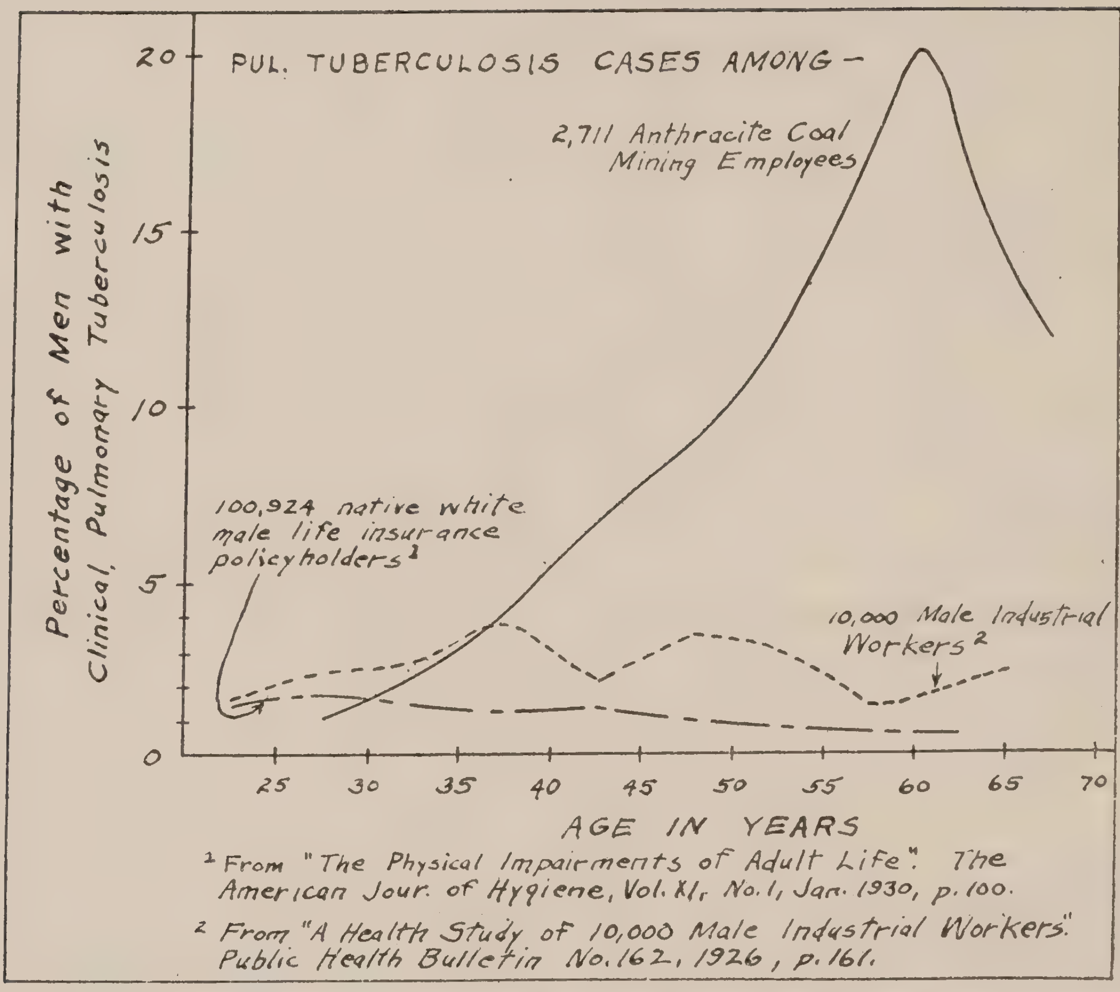


FIGURE 21.—Percentage of persons having clinical pulmonary tuberculosis, by age, in each of three male groups.

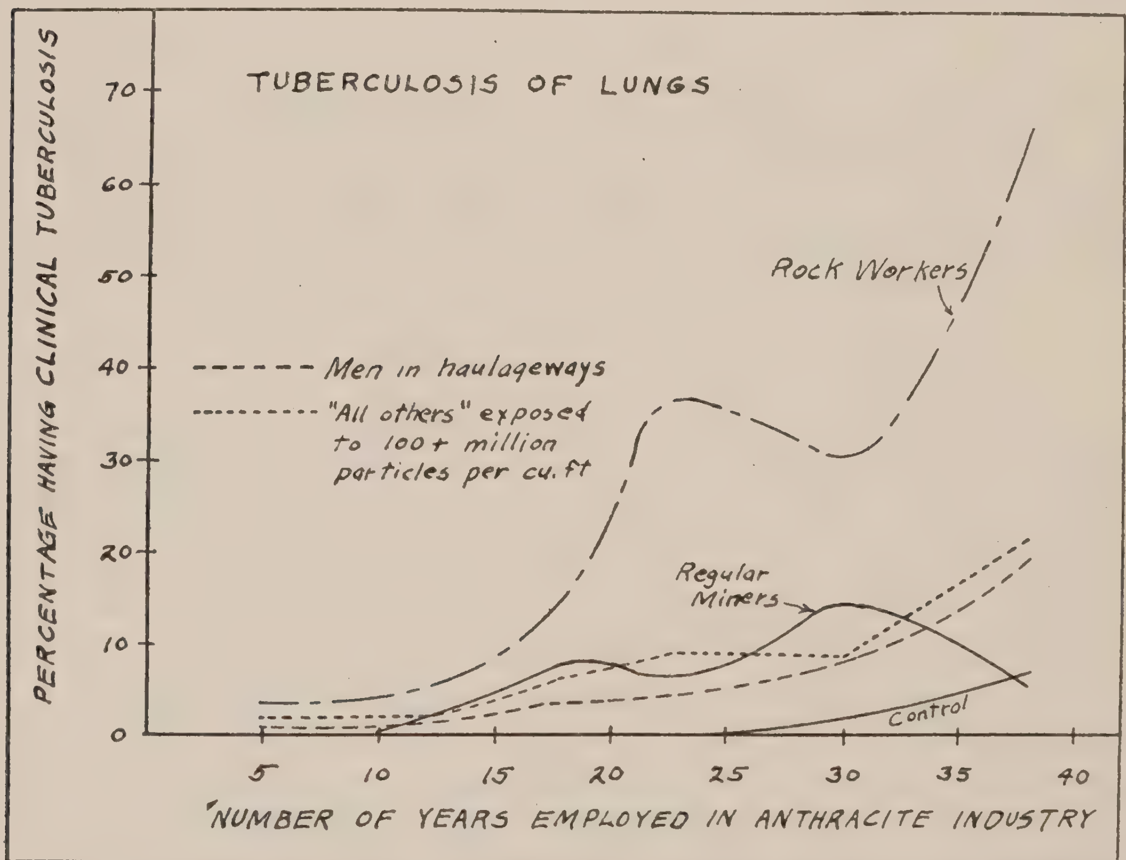


FIGURE 22.—Percentage of men having clinical pulmonary tuberculosis, by length of service in the anthracite coal mining industry.

Among the anthracite workers examined, the clinical tuberculosis rate was below normal in the younger adult ages, but at ages 35 to 44 clinical pulmonary tuberculosis was diagnosed in about 5 percent of the hard-coal mining employees; at ages 45 to 54 in 10 percent; and at ages 55 to 64 in 20 percent. No such rise with age occurred in any general population group for which comparable data are available (cf. table 36).

The prevalence of tuberculosis was greatest among the rock workers. The next to the highest rate occurred among anthracite workers who had changed more than 5 years previously from very dusty to

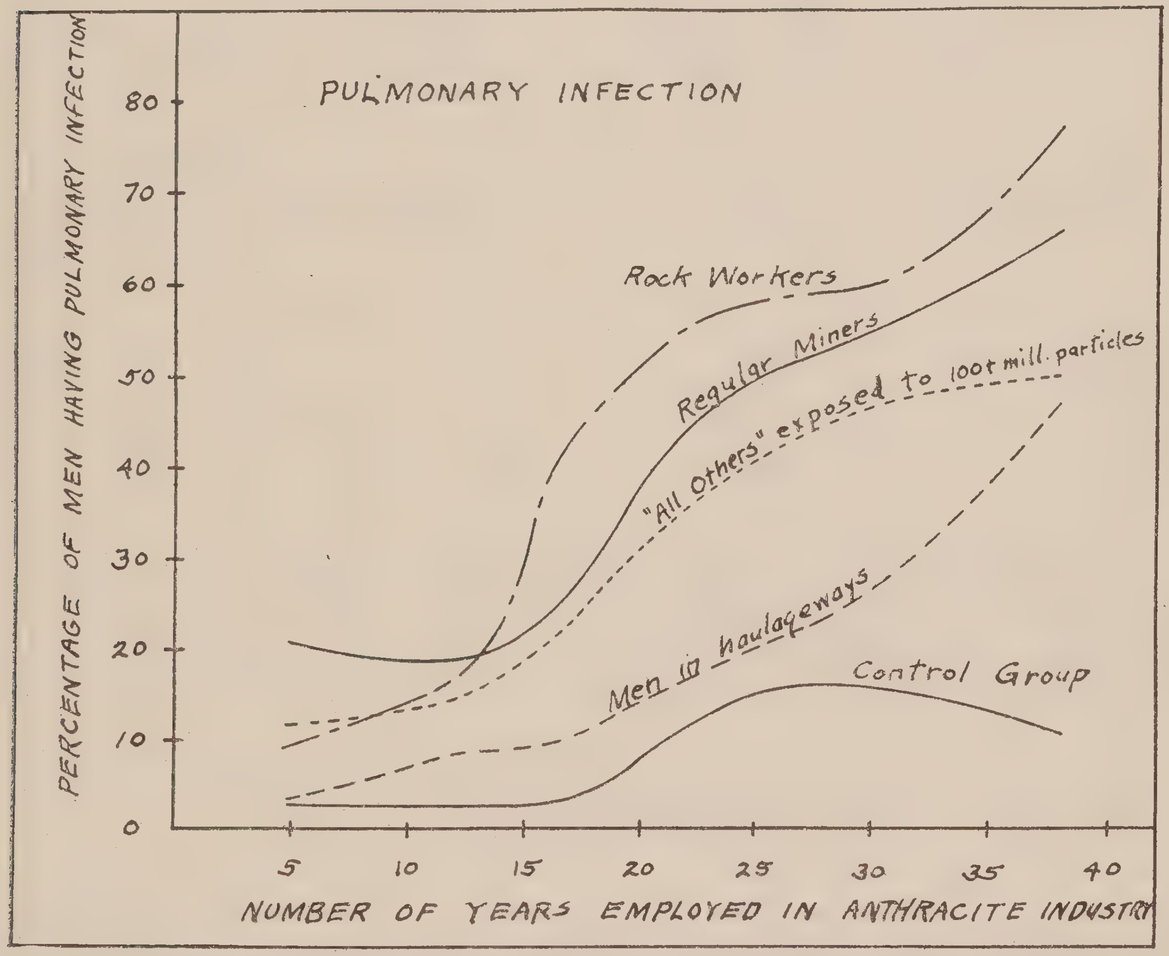


FIGURE 23.—Percentage of men having pulmonary infection including clinical pulmonary tuberculosis, by length of service in the anthracite coal mining industry.

relatively nondusty occupations in the industry. The third highest rate was exhibited among persons who had had appreciable exposure to harmful dusts in other industries. Among the regular miners working at the face the rate was definitely higher than in the control group which showed a prevalence rate of less than 1 percent.

When the term of service exceeded 20 years, more than 2 or 3 of which involved exposure to heavy concentrations of rock dust, about 37 percent of such employees (classified as rock workers) showed evidence of pulmonary tuberculosis. Service of 25 to 34 years was associated with a tuberculosis rate of 8 percent among nonrock workers employed in the haulageways, of 14 percent among

the regular miners, but with a rate under 2 percent among men exposed to less than 5 million dust particles per cubic foot of air.

PREVALENCE OF PULMONARY INFECTION ACCORDING TO LENGTH OF SERVICE

Pulmonary infection including clinical tuberculosis increased with length of service more rapidly among the men in the haulageways than in the control group, and much more rapidly among the regular miners. The highest rates of pulmonary infection, however, occurred among persons employed more than 15 years, of which more than 2 or 3 years was spent in rock drilling or loading. (Cf. tables 37 and 38).

TABLE 37.—*Number of men examined in each specified group of workers, classified according to length of service in the anthracite coal mining industry*

Number of years in anthracite industry	All men examined	Control group [1]	Group C (in haulageways)[2]	Group D (rock workers)	Regular miners [3]	All others exposed to 5–99 million particles [4]	All others exposed to 100 or more million particles [4]
All years	2,711	361	602	151	426	247	762
Less than 10	748	102	243	31	44	54	219
10 to 14	418	44	104	41	49	45	108
15 to 19	334	65	59	15	52	47	85
20 to 24	419	58	47	25	114	38	132
25 to 34	525	63	76	30	132	26	172
35 and over	267	29	73	9	35	37	46

[1] Men whose dust exposure averaged less than 5,000,000 particles per cubic foot.
[2] Men in nonmining occupations underground, except rock workers, whose average exposure was more than 5,000,000 dust particles per cubic foot of air.
[3] Contract miners and their helpers who had done little rock work and who had spent most of their working time to date in the occupation of mining hard coal.
[4] Exclusive of two groups: (*a*) Men who had had appreciable exposure to harmful dusts in other industries; and (*b*) men who had changed more than 5 years previously from very dusty to relatively nondusty occupations in the anthracite industry.

TABLE 38.—*Number and percentage of men examined having pulmonary infection, and number and percentage having clinical pulmonary tuberculosis, by length of service in the anthracite coal mining industry*

Number of years in anthracite industry	All men examined	Control group [1]	Group C (in haulageways) [2]	Group D (rock workers)	Regular miners [3]	All others exposed to 5–99 million particles [4]	All others exposed to 100 or more million particles [4]
PERCENTAGE HAVING PULMONARY INFECTION INCLUDING CLINICAL PULMONARY TUBERCULOSIS							
All years	23.9	7.2	14.1	37.1	42.0	12.6	27.8
Less than 10	8.2	2.9	3.3	9.7	20.5	1.9	11.4
10 to 14	13.2	2.3	8.7	17.1	18.4	8.9	14.8
15 to 19	16.5	3.1	10.2	46.7	26.9	6.4	23.5
20 to 24	33.4	12.1	17.0	56.0	45.6	21.1	36.4
25 to 34	41.7	15.9	26.3	60.0	54.5	19.2	46.5
35 and over	44.2	10.3	46.6	77.7	65.7	27.0	50.0

[1] Men having dust exposure which averaged less than 5,000,000 particles per cubic foot.
[2] Men in nonmining occupations underground, except rock workers, whose average exposure was more than 5,000,000 dust particles per cubic foot of air.
[3] Contract miners and their helpers who had done little rock work and who had spent most of their working time to date in the occupation of mining hard coal.
[4] Part of group A (men exposed to dust containing less than 5 percent free silica). Those who had had appreciable exposure to harmful dusts in other industries, and men who had changed more than 5 years previously from very dusty to relatively nondusty occupations in the anthracite industry, were not included in group A.

TABLE 38.—*Number and percentage of men examined having pulmonary infection, and number and percentage having clinical pulmonary tuberculosis, by length of service in the anthracite coal mining industry*—Continued.

Number of years in anthracite industry	All men examined	Control group	Group C (in haulage-ways)	G.oup D (rock-workers)	Regular miners	All others exposed to 5–99 million particles	All others exposed to 100 or more million particles
PERCENTAGE HAVING CLINICAL PULMONARY TUBERCULOSIS							
All years	6.1	0.8	4.3	19.2	7.7	3.6	6.2
Less than 10	1.2	0	.4	3.2	0	0	1.8
10 to 14	2.2	0	1.0	4.9	2.0	2.2	1.9
15 to 19	4.2	0	3.4	13.3	7.7	0	5.9
20 to 24	7.9	0	4.3	36.0	6.1	2.6	8.3
25 to 34	10.7	1.6	7.9	30.0	14.4	11.5	8.7
35 and over	16.9	6.9	19.2	66.6	5.7	10.8	21.7
NUMBER OF MEN EXAMINED HAVING PULMONARY INFECTION INCLUDING CLINICAL PULMONARY TUBERCULOSIS							
All years	648	26	85	56	179	31	212
Less than 10	61	3	8	3	9	1	25
10 to 14	55	1	9	7	9	4	16
15 to 19	55	2	6	7	14	3	20
20 to 24	140	7	8	14	52	8	48
25 to 34	219	10	20	18	72	5	80
35 and over	118	3	34	7	23	10	23
NUMBER OF MEN EXAMINED HAVING CLINICAL PULMONARY TUBERCULOSIS							
All years	166	3	26	29	33	9	47
Less than 10	9	0	1	1	0	0	4
10 to 14	9	0	1	2	1	1	2
15 to 19	14	0	2	2	4	0	5
20 to 24	33	0	2	9	7	1	11
25 to 34	56	1	6	9	19	3	15
35 and over	45	2	14	6	2	4	10

PREVALENCE OF PULMONARY INFECTION ACCORDING TO STAGE OF ANTHRACO-SILICOSIS

Pulmonary infection (tuberculous and nontuberculous) was found among 58 percent of the men having first stage anthraco-silicosis and in 92 percent of those in the second or third stage. The corresponding percentages for clinical tuberculosis were 15 and 43, respectively. In the age group 65 and over about 27 percent of the men having stage 1 anthraco-silicosis were clinically tuberculous. (Cf. tables 39 and 40).

TABLE 39.—*Number of men examined, classified according to stage of anthraco-silicosis, and by age*

Stage of anthraco-silicosis	All adult ages	Adult ages below 35	35 to 44	45 to 54	55 to 64	65 and over
All men examined	2,711	1,002	829	605	224	51
All not having anthraco-silicosis	2,095	994	646	325	99	31
Stage 1 anthraco-silicosis	510	8	169	236	82	15
Stage 2 or 3 anthraco-silicosis	106	0	14	44	43	5

TABLE 40.—*Number and percentage of men examined having pulmonary infection (including clinical pulmonary tuberculosis), and number and percentage having clinical pulmonary tuberculosis, classified according to stage of anthraco-silicosis and by age*

Stage of anthraco-silicosis	Pulmonary infection including clinical pulmonary tuberculosis						Clinical pulmonary tuberculosis					
	Age group						Age group					
	All ages	Under 35	35–44	45–54	55–64	65 and over	All ages	Under 35	35–44	45–54	55–64	65 and over
	PERCENTAGE OF MEN EXAMINED											
All men examined	23.9	6.1	25.9	38.5	53.5	37.3	6.1	1.0	5.3	10.1	20.1	11.8
All not having anthraco-silicosis	12.2	5.7	15.3	19.4	30.3	22.6	2.0	.7	1.9	3.7	9.1	6.5
Stage 1 anthraco-silicosis	57.6	(1)	61.6	54.2	59.8	60.0	15.3	(1)	15.4	12.7	18.3	26.7
Stage 2 or 3 anthraco-silicosis	92.4	------	85.6	95.4	95.2	(1)	43.4	------	42.9	43.2	48.8	(1)
	NUMBER OF MEN HAVING INFECTION SPECIFIED											
All men examined	648	61	215	233	120	19	166	10	44	61	45	6
All not having anthraco-silicosis	256	57	99	63	30	7	42	7	12	12	9	2
Stage 1 anthraco-silicosis	294	4	104	128	49	9	78	3	26	30	15	4
Stage 2 or 3 anthraco-silicosis	98	0	12	42	41	3	46	0	6	19	21	0

[1] Less than 10 men examined in the group.

10. PHYSICAL IMPAIRMENT CAUSING DECREASED CAPACITY FOR WORK

Evaluation of physical fitness for arduous work was based largely on the functional exercise test, described on page 52, which afforded knowledge of the cardiac and respiratory response to exercise. In the interpretation of results of the test, certain factors were considered, such as age, weight, present occupation, whether the test was made before or after a day's work, and the extent to which the examinee cooperated.

About 22 percent of all the men examined were found to have some physical impairment sufficient to decrease their capacity for work. This rate includes slight as well as moderate or marked physical impairment from any cause. The percentage showing moderate or marked impairment from any cause was about 6.

Approximately 13 percent showed disability in which pulmonary infection was contributory. About 4 percent of the men examined had clinical pulmonary tuberculosis which contributed to disability.

TABLE 41.—*Number and percentage of men in specified groups of anthracite coal mining employees showing physical impairment sufficient to decrease capacity for work*

Groups of anthracite coal mining employees	Physical impairment causing decreased capacity for work: From any cause: Slight, moderate or marked	From any cause: Moderate or marked	From causes other than pulmonary disease: Slight, moderate or marked	From causes other than pulmonary disease: Moderate or marked	Pulmonary infection contributory[1]: Slight, moderate or marked	Pulmonary infection contributory[1]: Moderate or marked	Clinical pulmonary tuberculosis contributory: Slight, moderate or marked	Clinical pulmonary tuberculosis contributory: Moderate or marked
PERCENTAGE OF MEN EXAMINED								
All men examined	21.7	5.8	9.0	1.4	12.7	4.4	4.3	2.4
Control group[2]	9.7	1.7	8.6	1.7	1.1	0	.6	0
Group C (in haulageways)[3]	12.1	2.8	5.8	1.1	6.3	1.7	2.7	1.0
Group D (rock workers)	35.8	12.6	9.3	1.3	26.5	11.3	14.6	8.6
Group B (regular miners)[4]	39.0	9.9	12.5	1.0	26.5	8.9	6.1	4.0
Previous exposure to other dusts[5]	27.2	7.8	13.6	2.0	13.6	5.8	6.8	4.9
Special group[6]	64.4	28.8	32.2	5.1	32.2	23.7	13.6	11.9
All others exposed to 5–99 million particles[7]	12.6	2.0	7.7	1.6	4.9	.4	2.0	.4
All others exposed to 100+ million particles[7]	21.3	5.6	7.5	1.3	13.8	4.3	4.1	2.2
NUMBER OF MEN EXAMINED SHOWING PHYSICAL IMPAIRMENT CAUSING DECREASED CAPACITY FOR WORK								
All men examined	587	157	242	38	345	119	117	66
Control group[2]	35	6	31	6	4	0	2	0
Group C (in haulageways)[3]	73	17	35	7	38	10	16	6
Group D (rock workers)	54	19	14	2	40	17	22	13
Group B (regular miners)[4]	166	42	53	4	113	38	26	17
Previous exposure to other dusts[5]	28	8	14	2	14	6	7	5
Special group[6]	38	17	19	3	19	14	8	7
All others exposed to 5–99 million particles[7]	31	5	19	4	12	1	5	1
All others exposed to 100+ million particles[7]	162	43	57	10	105	33	31	17

[1] Including clinical pulmonary tuberculosis.
[2] Men whose dust exposure averaged less than 5 million particles per cubic foot.
[3] Men in non-mining occupations underground, except rock workers, whose average exposure was more than 5 million particles per cubic foot of air.
[4] Contract miners and their helpers who had done little rock work and who had spent most of their working time to date in the occupation of mining hard coal.
[5] Men who had had appreciable exposure to harmful dusts in other industries.
[6] Men who had changed more than 5 years previously from very dusty to relatively nondusty occupations in the anthracite industry.
[7] Part of group A (men exposed to dust containing less than 5 percent free silica).

Wide differences were found in the extent of physical impairment in the several occupational groups. The highest rate of disability from all causes combined was found in the group of men which had changed more than 5 years prior to the date of examination from very dusty to relatively nondusty occupations in the industry. In a number of cases the change in occupation probably was made on account of physical condition. Miners at the coal face, rock workers, and men who had had appreciable exposure to harmful dusts in other industries also showed evidence of much greater physical impairment than was found in the control group.

Moderate or marked physical impairment from any cause was found in 1.7 percent of the control group, in 9.9 percent of the regular miners, and among 12.6 percent of the rock workers.

PERCENTAGE SHOWING DISABILITY ACCORDING TO LENGTH OF SERVICE

A marked tendency toward increase in the proportion having physical impairments with increase in the number of years of employment in anthracite is shown in table 42 and illustrated in figures 24 to 27,

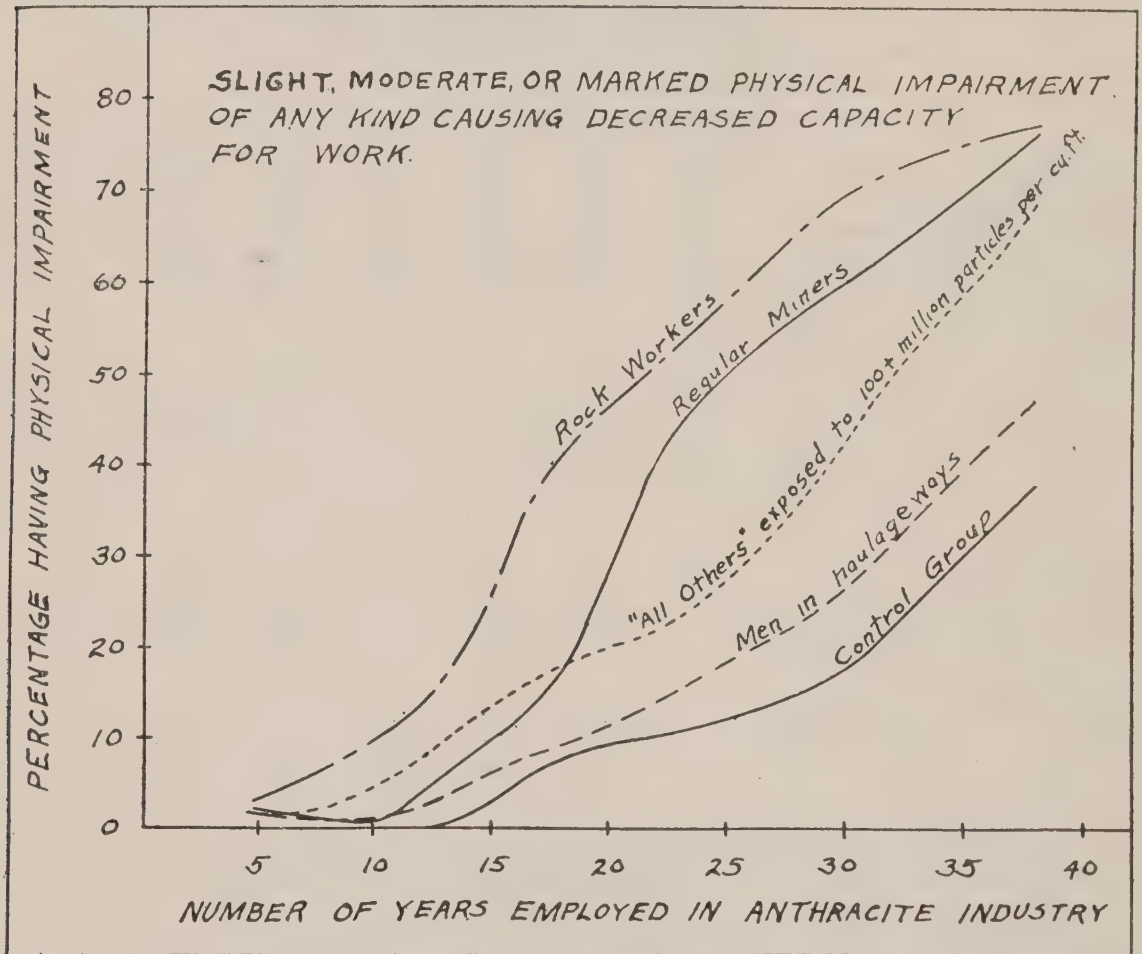


FIGURE 24.—Percentage of men having slight, moderate, or marked physical impairment of any kind sufficient to decrease capacity for work, by length of service in the anthracite coal mining industry.

inclusive. This tendency is manifested whether one considers disability of any kind, disability in which pulmonary infection was contributory, or disability due largely to tuberculosis. In each case the occupational groups arrayed themselves according to extent of physical impairment as follows: (1) Rock workers; (2) regular miners; (3) all others exposed to more than 100 million dust particles per cubic foot of air; and (4) men in haulageways except rock workers.

When the number of years in anthracite was less than 10, there was little disability in any group. When the period of employment was less than 20 years, no group with the exception of rock workers showed moderate or marked disability appreciably in excess of that among the controls. However, an excess in the prevalence of slight impairment was found among the regular miners and among others in group A who had worked from 10 to 20 years in atmospheres con-

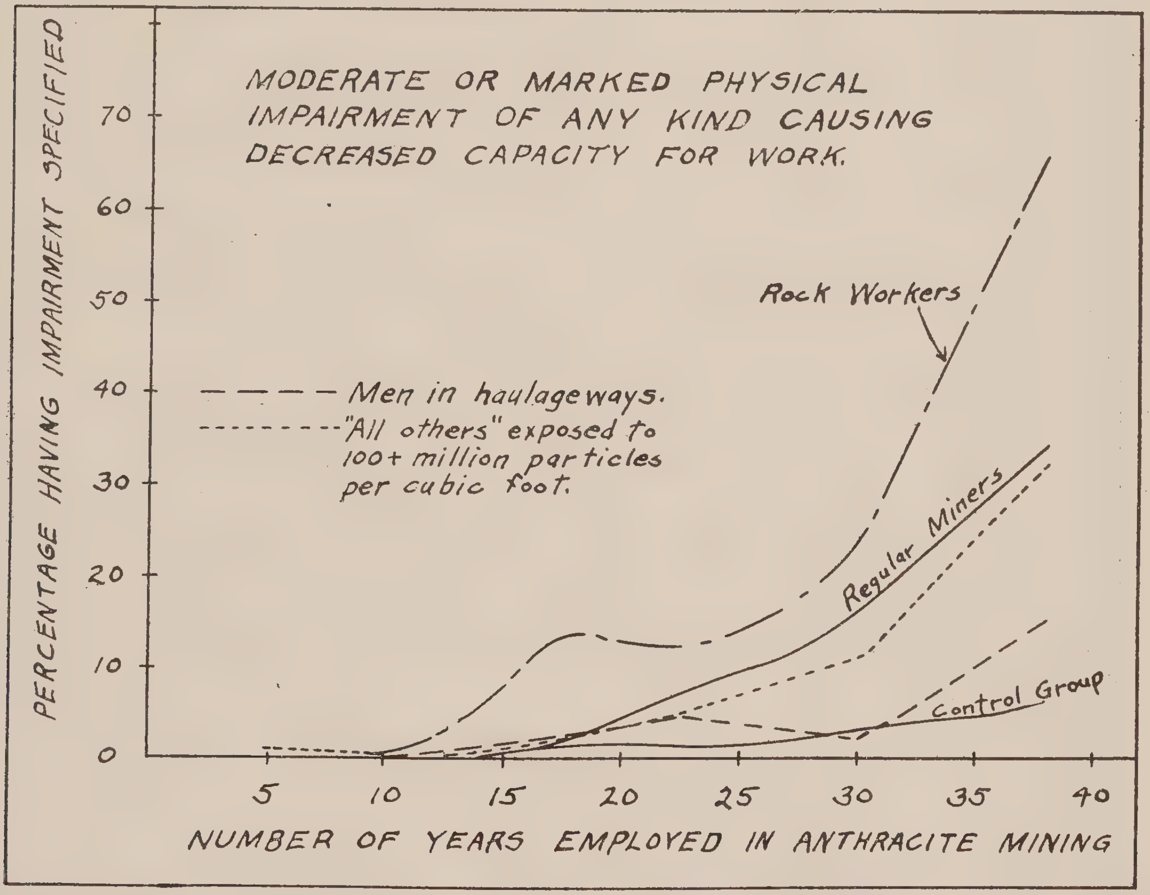


FIGURE 25.—Percentage of men having moderate or marked physical impairment of any kind causing decreased capacity for work, by length of service in the anthracite coal mining industry.

taining more than 100 million dust particles per cubic foot. The rates mounted sharply thereafter, especially among the rock workers and the regular miners at the face. The percentage showing physical impairment increased with length of service more slowly among the men in the nonmining occupations underground, but their rates nevertheless were definitely greater than those of the control group. (Cf. table 42.)

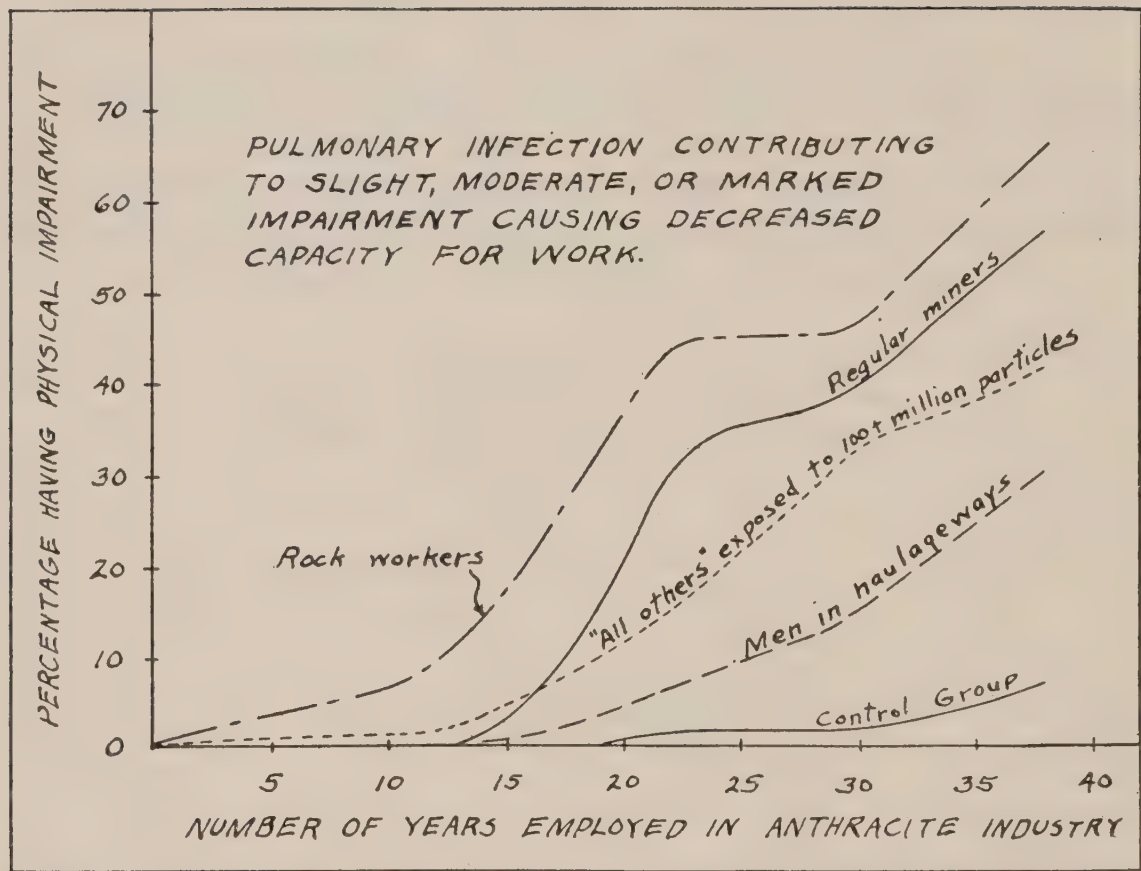


FIGURE 26.—Percentage of men having pulmonary infection contributory to slight, moderate, or marked impairment causing decreased capacity for work, by length of service in the anthracite coal mining industry.

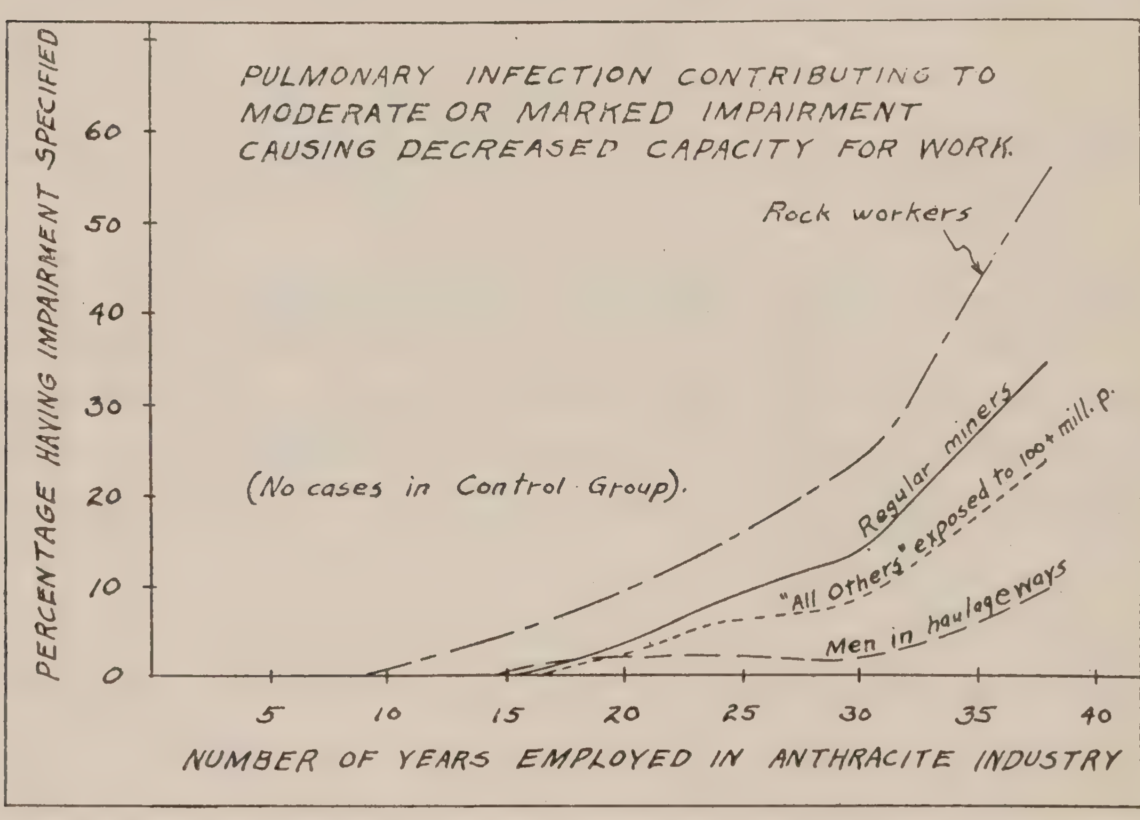


FIGURE 27.—Percentage of men having pulmonary infection contributory to moderate or marked impair ment causing decreased capacity for work, by length of service in the anthracite coal mining industry.

TABLE 42.—*Number and percentage of men showing physical impairment sufficient to decrease capacity for work, by length of service in the anthracite coal mining industry*

Number of years in anthracite industry	Percentage showing physical impairment							Number showing physical impairment						
	All men examined	Control group[1]	Men in haulageways[2]	Rock workers	Regular miners[3]	All others exposed to 5–99 million particles per cubic foot[4]	All others exposed to 100 or more million particles per cubic foot[4]	All men examined	Control group[1]	Men in haulageways[2]	Rock workers	Regular miners[3]	All others exposed to 5–99 million particles per cubic foot[4]	All others exposed to 100 or more million particles per cubic foot[4]
SLIGHT, MODERATE, OR MARKED PHYSICAL IMPAIRMENT OF ANY KIND SUFFICIENT TO DECREASE CAPACITY FOR WORK														
All years of service	21.7	9.7	12.1	35.8	39.0	12.6	21.3	587	35	73	54	166	31	162
Less than 10	2.5	2.0	1.2	3.2	0	1.9	1.8	19	2	3	1	0	1	4
10 to 14	6.2	0	2.9	14.6	4.1	0	8.3	26	0	3	6	2	0	9
15 to 19	13.8	7.7	8.5	40.0	15.4	6.4	17.6	46	5	5	6	8	3	15
20 to 24	26.5	10.3	14.9	52.0	43.0	7.9	22.0	111	6	7	13	49	3	29
25 to 34	42.7	17.5	26.3	70.0	60.6	19.2	42.4	224	11	20	21	80	5	73
35 and over	60.3	37.9	47.9	77.7	77.1	51.4	69.6	161	11	35	7	27	19	32
MODERATE OR MARKED PHYSICAL IMPAIRMENT OF ANY KIND CAUSING DECREASED CAPACITY FOR WORK														
All years of service	5.8	1.7	2.8	12.6	9.9	2.0	5.6	157	6	17	19	42	5	43
Less than 10	.1	0	0	0	0	0	.5	1	0	0	0	0	0	1
10 to 14	1.0	0	1.0	2.4	0	0	0	4	0	1	1	0	0	0
15 to 19	2.4	1.5	1.7	13.3	1.9	0	2.4	8	1	1	2	1	0	2
20 to 24	5.5	1.7	4.3	12.0	7.0	2.6	4.5	23	1	2	3	8	1	6
25 to 34	11.2	3.2	2.6	23.3	15.9	7.7	11.0	59	2	2	7	21	2	19
35 and over	23.2	6.9	15.1	66.6	34.3	5.4	32.6	62	2	11	6	12	2	15
PULMONARY INFECTION CONTRIBUTING TO SLIGHT, MODERATE, OR MARKED IMPAIRMENT CAUSING DECREASED CAPACITY FOR WORK[5]														
All years of service	12.7	1.1	6.3	26.5	26.5	4.9	13.8	345	4	38	40	113	12	105
Less than 10	.9	0	.4	3.2	0	0	.9	7	0	1	1	0	0	2
10 to 14	2.2	0	0	9.8	0	0	1.9	9	0	0	4	0	0	2
15 to 19	5.1	0	1.7	26.7	9.6	0	7.1	17	0	1	4	5	0	6
20 to 24	18.1	1.7	6.4	44.0	31.6	5.3	15.2	76	1	3	11	36	2	20
25 to 34	27.2	1.6	14.5	46.7	39.4	3.8	32.6	143	1	11	14	52	1	56
35 and over	34.8	6.9	30.1	66.6	57.1	24.3	41.3	93	2	22	6	20	9	19

[1] Men having dust exposure which averaged less than 5,000,000 particles per cubic foot.
[2] Men in nonmining occupations underground, except rock workers, whose average exposure was more than 5,000,000 dust particles per cubic foot of air.
[3] Contract miners and their helpers who had done little rock work and who had spent most of their working time to date in the occupation of mining hard coal.
[4] With the exception of 2 groups: (*a*) men who had had appreciable exposure to harmful dusts in other industries; and (*b*) men who had changed more than 5 years previously from very dusty to relatively nondusty occupations in the anthracite industry.
[5] Cases of clinical tuberculosis of the lungs were included.

TABLE 42.—*Number and percentage of men showing physical impairment sufficient to decrease capacity for work, by length of service in the anthracite coal mining industry*—Continued

Number of years in anthracite industry	Percentage showing physical impairment: All men examined	Control group	Men in haulageways	Rock workers	Regular miners	All others exposed to 5–99 million particles per cubic foot	All others exposed to 100 or more million particles per cubic foot	Number showing physical impairment: All men examined	Control group	Men in haulageways	Rock workers	Regular miners	All others exposed to 5–99 million particles per cubic foot	All others exposed to 100 or more million particles per cubic foot
PULMONARY INFECTION CONTRIBUTING TO MODERATE OR MARKED IMPAIRMENT CAUSING DECREASED CAPACITY FOR WORK [5]														
All years of service	4.4	0	1.7	11.3	8.9	0.4	4.3	119	0	10	17	38	1	33
Less than 10	.1	0	0	0	0	0	.5	1	0	0	0	0	0	1
10 to 14	.5	0	0	2.4	0	0	0	2	0	0	1	0	0	0
15 to 19	1.5	0	1.7	6.7	1.9	0	1.2	5	0	1	1	1	0	1
20 to 24	4.5	0	2.1	12.0	6.1	0	4.5	19	0	1	3	7	0	6
25 to 34	8.6	0	1.3	23.3	13.6	0	8.1	45	0	1	7	18	0	14
35 and over	17.6	0	9.6	55.6	34.3	2.7	23.9	47	0	7	5	12	1	11
CLINICAL TUBERCULOSIS OF THE LUNGS CONTRIBUTING TO SLIGHT, MODERATE, OR MARKED IMPAIRMENT CAUSING DECREASED CAPACITY FOR WORK														
All years of service	4.3	0.6	2.7	14.6	6.1	2.0	4.1	117	2	16	22	26	5	31
Less than 10	.5	0	.4	0	0	0	.9	4	0	1	0	0	0	2
10 to 14	.5	0	0	2.4	0	0	0	2	0	0	1	0	0	0
15 to 19	2.4	0	1.7	13.3	3.8	0	2.4	8	0	1	2	2	0	2
20 to 24	5.7	0	0	28.0	6.1	0	5.3	24	0	0	7	7	0	7
25 to 34	8.0	0	6.6	23.3	11.4	3.8	7.0	42	0	5	7	15	1	12
35 and over	13.9	6.9	12.3	55.6	5.7	10.8	17.4	37	2	9	5	2	4	8
CLINICAL TUBERCULOSIS OF THE LUNGS CONTRIBUTING TO MODERATE OR MARKED IMPAIRMENT CAUSING DECREASED CAPACITY FOR WORK														
All years of service	2.4	0	1.0	8.6	4.0	0.4	2.2	66	0	6	13	17	1	17
Less than 10	.1	0	0	0	0	0	.5	1	0	0	0	0	0	1
10 to 14	.2	0	0	0	0	0	0	1	0	0	0	0	0	0
15 to 19	1.5	0	1.7	6.7	1.9	0	1.2	5	0	1	1	1	0	1
20 to 24	2.9	0	0	8.0	3.5	0	3.0	12	0	0	2	4	0	4
25 to 34	4.6	0	0	20.0	7.6	0	3.5	24	0	0	6	10	0	6
35 and over	8.6	0	6.8	44.4	5.7	2.7	10.9	23	0	5	4	2	1	5

[5] Cases of clinical tuberculosis of the lungs were included.

TABLE 43.—*Number and percentage of specified groups of anthracite coal mining employees showing physical impairment sufficient to decrease capacity for work, by age*

Age group	Percentage of men examined showing disability [1]							Number of men examined showing disability [1]						
	All men examined	Control group [2]	Group C (in haulageways) [3]	Group D (rock workers)	Regular miners [4]	"All others" exposed to 5–99 mill. particles [5]	"All others" exposed to 100+ mill. particles [5]	All men examined	Control group [2]	Group C (in haulageways) [3]	Group D (rock workers)	Regular miners [4]	"All others" exposed to 5–99 mill. particles [5]	"All others" exposed to 100+ mill. particles [5]
SLIGHT, MODERATE, OR MARKED DISABILITY FROM ANY CAUSE														
35 to 44	16.8	7.8	7.1	36.1	25.8	5.9	18.2	139	7	9	22	40	4	50
45 to 54	38.7	14.1	24.5	55.6	53.2	16.1	42.4	234	9	23	20	82	5	72
55 and over	72.0	41.0	70.4	80.0	81.1	61.2	87.5	198	16	38	12	43	19	35
MODERATE OR MARKED DISABILITY FROM ANY CAUSE														
35 to 44	2.7	1.1	1.6	3.3	5.2	0	2.5	22	1	2	2	8	0	7
45 to 54	9.1	1.6	4.3	25.0	9.1	6.5	11.8	55	1	4	9	14	2	20
55 and over	28.0	7.7	20.4	53.3	37.7	9.7	35.0	77	3	11	8	20	3	14
SLIGHT, MODERATE, OR MARKED DISABILITY, PULMONARY INFECTION CONTRIBUTORY [6]														
35 to 44	9.9	0	2.4	26.2	18.1	2.9	10.5	82	0	3	16	28	2	29
45 to 54	23.5	3.1	14.9	44.4	32.5	3.2	28.8	142	2	14	16	50	1	49
55 and over	42.9	5.1	37.0	53.3	66.0	29.0	62.5	118	2	20	8	35	9	25

[1] Physical impairment causing decreased capacity for work.
[2] Men whose dust exposure averaged less than 5 million particles per cubic foot.
[3] Men in nonmining occupations underground, except rock workers, whose average exposure was more than 5 million dust particles per cubic foot of air.
[4] Contract miners and their helpers who had done little rock work and who had spent most of their working time to date in the occupation of mining hard coal.
[5] Exclusive of men who had had appreciable exposure to harmful dusts in other industries and of men who had changed more than five years previously from very dusty to relatively nondusty occupations in the anthracite industry.
[6] Cases in which pulmonary infection including clinical tuberculosis of the lungs was regarded as contributing to disability.

TABLE 43.—*Number and percentage of specified groups of anthracite coal mining employees showing physical impairment sufficient to decrease capacity for work, by age*—Continued

Age group	Percentage of men examined showing disability [1]							Number of men examined showing disability [1]						
	All men examined	Control group	Group C (in haulage-ways)	Group D (rock workers)	Regular miners	"All others" exposed to 5–99 mill. particles	"All others" exposed to 100+ mill. particles	All men examined	Control group	Group C (in haulage-ways)	Group D (rock workers)	Regular miners	"All others" exposed to 5–99 mill. particles	"All others" exposed to 100+ mill. particles
MODERATE OR MARKED DISABILITY, PULMONARY INFECTION CONTRIBUTORY [6]														
35 to 44	1.8	0	0.8	1.6	4.5	0	1.5	15	0	1	1	7	0	4
45 to 54	7.4	0	2.1	25.0	7.8	0	10.0	45	0	2	9	12	0	17
55 and over	20.7	0	13.0	46.7	35.8	3.2	25.0	57	0	7	7	19	1	10
SLIGHT, MODERATE, OR MARKED DISABILITY, TUBERCULOSIS CONTRIBUTORY [7]														
35 to 44	3.1	0	0.8	14.8	3.9	0	2.9	26	0	1	9	6	0	8
45 to 54	6.9	1.6	6.4	16.7	6.5	3.2	8.2	42	1	6	6	10	1	14
55 and over	16.7	2.6	14.8	46.7	18.9	12.9	17.5	46	1	8	7	10	4	7
MODERATE OR MARKED DISABILITY, TUBERCULOSIS CONTRIBUTORY [7]														
35 to 44	1.1	0	0.8	1.6	1.9	0	0.7	9	0	1	1	3	0	2
45 to 54	4.0	0	1.1	16.7	3.2	0	5.3	24	0	1	6	5	0	9
55 and over	11.3	0	7.4	40.0	17.0	3.2	10.0	31	0	4	6	9	1	4

[6] Cases in which pulmonary infection including clinical tuberculosis of the lungs was regarded as contributing to disability.
[7] Cases in which clinical tuberculosis of the lungs was regarded as contributing to disability.

PERCENTAGE SHOWING DISABILITY ACCORDING TO AGE, WITH SPECIAL REFERENCE TO THE AGE GROUP 55 AND OVER

The number and percentage showing disability at different ages appear in table 43. Physical impairment increased markedly with age in all groups, but the effect of dust may be seen in the wide

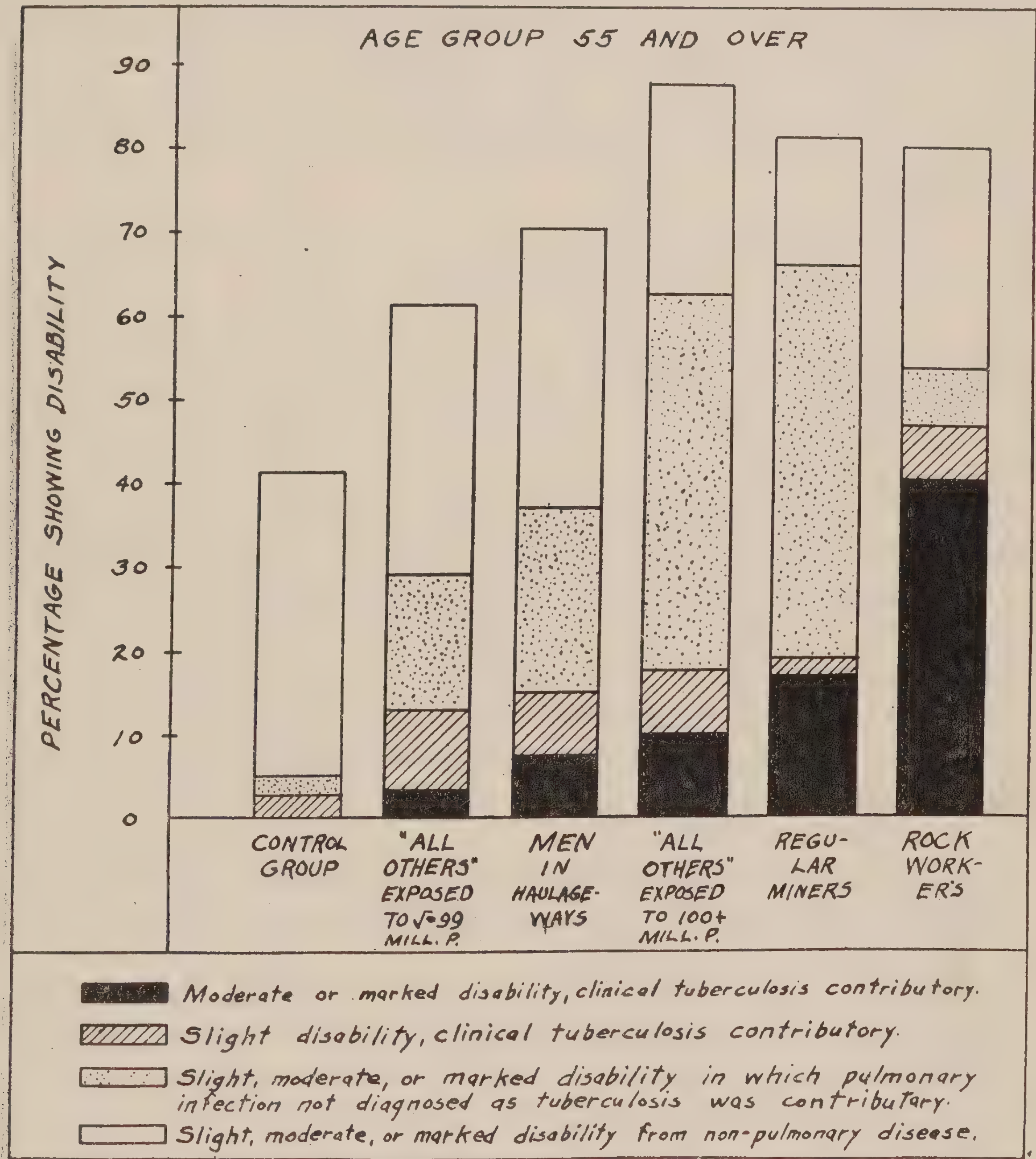


FIGURE 28.—Relative importance of different causes of physical impairment at ages 55 and over in specified groups of anthracite coal mining employees.

differences for certain groups in comparison with men at the same ages in the control group.

The results for the age group 55 and over are of special interest, because the cumulative effects of dust exposure may be expected to be most evident at the higher ages. There were not many old men in

the age group 55 and over. As shown in table 35, only a small proportion in this age group were above 65 except among the men used as controls.

Striking differences were found in the amount of disability from clinical tuberculosis among men at ages 55 and over in the various occupational groups. In this age group, 40 percent of the rock workers showed moderate or marked disability associated with clinical pulmonary tuberculosis, in contrast with less than 3 percent of the control group showing slight disability from this cause. Among the miners employed at the coal face, a large amount of disability occurred in which pulmonary infection, not diagnosed as tuberculosis, contributed to disability.

PERCENTAGE SHOWING DISABILITY ACCORDING TO STAGE OF ANTHRACO-SILICOSIS

The number and percentage of men showing disability, classified according to stage of anthraco-silicosis and by age are given in table 44. The number of men on whom these percentages are based may be found in table 39.

About 9 percent of the men not having anthraco-silicosis showed slight, moderate, or marked disability from some cause as compared with 57 percent in stage 1, and with 97 percent in stage 2 or 3 anthraco-silicosis. The corresponding percentages for moderate or marked disability from any cause were 1, 10, and 73, respectively.

Less than 3 percent of the men not having anthraco-silicosis showed disability in which pulmonary infection was contributory, as compared with 38 percent of the men in stage 1, and with 91 percent of those in stage 2 or 3 anthraco-silicosis.

About 11 percent of the men in stage 1, and about 43 percent of those in stage 2 or 3 showed physical impairment in which clinical tuberculosis contributed to the disability.

The above-mentioned percentages apply to all adult ages combined. In accordance with expectation, a larger proportion showed disability in a given stage of the disease at the higher than at the younger ages. The extent to which this tendency was manifested may be observed from the percentages shown for physical impairment at different ages.

TABLE 44.—*Number and percentage of anthracite coal mining employees showing physical impairment sufficient to decrease capacity for work, according to stage of anthraco-silicosis*

Stage of anthraco-silicosis	Percentage of men examined who showed disability						Number of men examined who showed disability					
	From any cause		Pulmonary infection contributory [1]		Tuberculosis contributory [2]		From any cause		Pulmonary infection contributory [1]		Tuberculosis contributory [2]	
	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked
ALL ADULT AGES												
All men examined	21.7	5.8	12.7	4.4	4.3	2.4	587	157	345	119	117	66
All not having anthraco-silicosis	9.4	1.3	2.7	.1	.9	.1	196	28	57	3	18	2
Stage 1 anthraco-silicosis	56.5	10.2	37.6	8.4	10.6	4.9	288	52	192	43	54	25
Stage 2 or 3 anthraco-silicosis	97.2	72.6	90.6	68.9	42.5	36.8	103	77	96	73	45	39
ADULT AGES BELOW 35												
All men examined	1.6	.3	.2	.2	.3	.2	16	3	3	2	3	2
All not having anthraco-silicosis	1.4	.2	.2	.1	.2	.1	14	2	2	1	2	1
Stage 1 anthraco-silicosis	(3)	(3)	(3)	(3)	(3)	(3)	2	1	1	1	1	1
Stage 2 or 3 anthraco-silicosis	----------	----------	----------	----------	----------	----------	0	0	0	0	0	0
AGE 35 TO 44 INCLUSIVE												
All men examined	16.8	2.7	9.9	1.8	3.1	1.1	139	22	82	15	26	9
All not having anthraco-silicosis	7.7	.9	1.9	0	.2	0	50	6	12	0	1	0
Stage 1 anthraco-silicosis	44.4	4.7	34.3	4.7	11.2	3.0	75	8	58	8	19	5
Stage 2 or 3 anthraco-silicosis	100.0	57.1	85.7	50.0	42.9	28.6	14	8	12	7	6	4

[1] Cases in which pulmonary infection was regarded as contributing to disability. Clinical tuberculosis cases were included.
[2] Cases in which clinical tuberculosis was regarded as contributing to disability.
[3] Less than 10 men examined in group specified.

TABLE 44.—*Number and percentage of anthracite coal mining employees showing physical impairment sufficient to decrease capacity for work, according to stage of anthraco-silicosis*—Continued

Stage of anthraco-silicosis	Percentage of men examined who showed disability						Number of men examined who showed disability					
	From any cause		Pulmonary infection contributory		Tuberculosis contributory		From any cause		Pulmonary infection contributory		Tuberculosis contributory	
	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked	Slight, moderate, or marked	Moderate, or marked
AGE 45 TO 54 INCLUSIVE												
All men examined	38.7	9.1	23.5	7.4	6.9	4.0	234	55	142	45	42	24
All not having anthraco-silicosis	17.5	1.8	4.6	0	1.5	0	57	6	15	0	5	0
Stage 1 anthraco-silicosis	57.6	8.5	36.9	7.2	8.1	3.8	136	20	87	17	19	9
Stage 2 or 3 anthraco-silicosis	93.2	65.9	90.9	63.6	40.9	34.1	41	29	40	28	18	15
AGE 55 TO 64 INCLUSIVE												
All men examined	68.8	25.9	44.6	21.4	18.3	12.1	154	58	100	48	41	27
All not having anthraco-silicosis	51.5	8.1	22.2	1.0	9.1	1.0	51	8	22	1	9	1
Stage 1 anthraco-silicosis	73.2	15.9	45.1	13.4	13.4	7.3	60	13	37	11	11	6
Stage 2 or 3 anthraco-silicosis	100.0	86.0	95.3	83.7	48.8	46.5	43	37	41	36	21	20
AGE 65 AND OVER												
All men examined	86.3	37.3	35.3	17.6	9.8	7.8	44	19	18	9	5	4
All not having anthraco-silicosis	77.4	19.4	19.4	3.2	3.2	0	24	6	6	1	1	0
Stage 1 anthraco-silicosis	100.0	66.7	60.0	40.0	26.7	26.7	15	10	9	6	4	4
Stage 2 or 3 anthraco-silicosis	(3)	(3)	(3)	(3)	(3)	(3)	5	3	3	2	0	0

[3] Less than 10 men examined in group specified.

CORRELATION OF PULMONARY INFECTION WITH DISABILITY

A comparison is afforded in figure 29 of the percentage of persons having pulmonary infection with the percentage showing disability, by occupational groups. Marked correlation is apparent. The group having the most infection and the most disability was composed of men who had changed more than 5 years previously from very dusty to relatively nondusty occupations in the anthracite industry. The next to the worst experience as regards both infection and disability was recorded for the regular miners. Rock workers ranked third, but they had more tuberculous infection than any

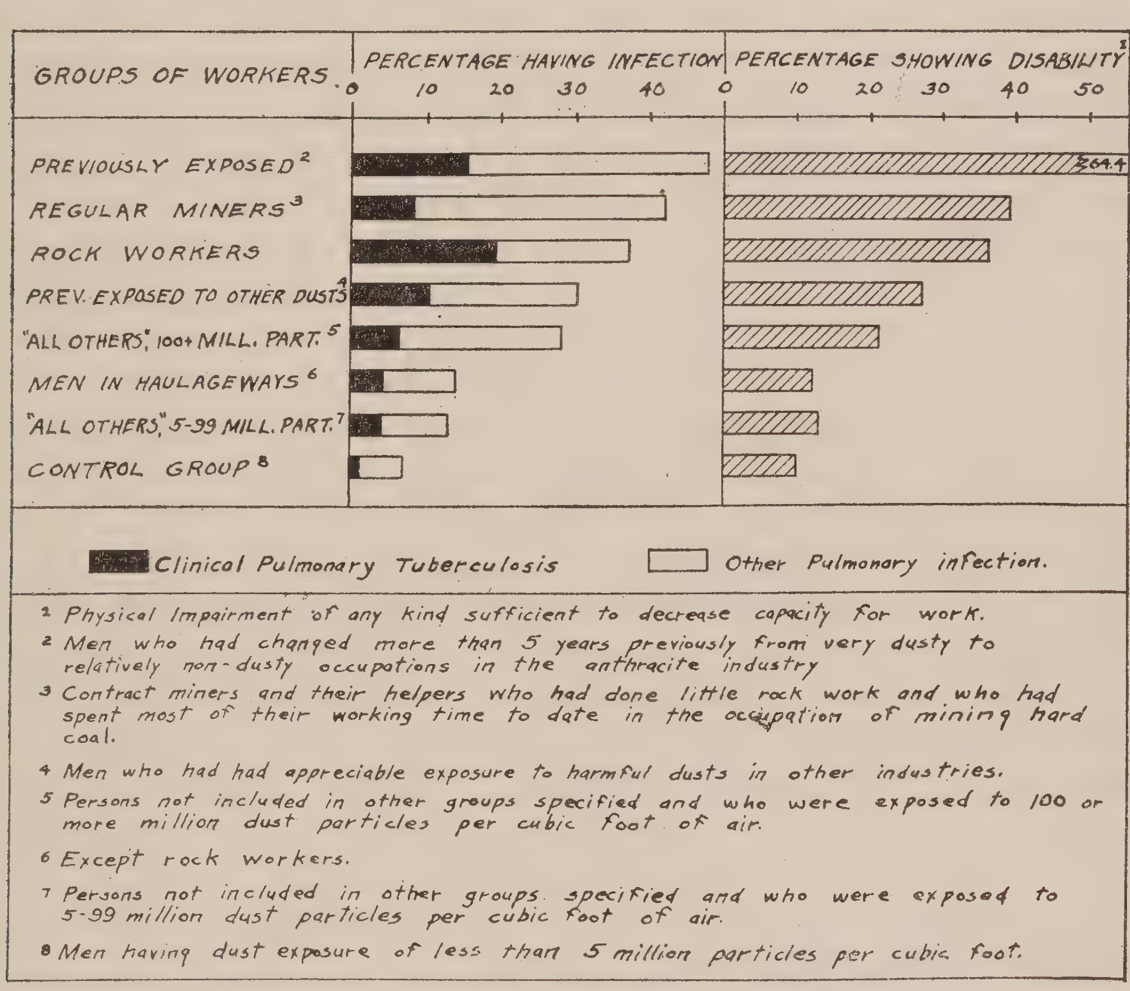


FIGURE 29.—Percentage of specified workers having pulmonary infection, and percentage showing physical impairment of any kind sufficient to decrease capacity for work.

other group. Next in order came the men who had had appreciable exposure to harmful dusts in other industries, followed by the group of "All others" exposed to more than 100 million dust particles per cubic foot. The health of persons engaged in underground work other than mining and rock drilling was found to be much better than that of any of the groups exposed to larger quantities of dust; nevertheless, they showed more pulmonary infection, more tuberculosis, and more disability than the group which had always worked in relatively dust-free air.

VII. MORTALITY AMONG THE FATHERS OF ANTHRACITE COAL WORKERS INTERVIEWED

The data presented thus far relate only to the health of persons exposed to anthracite dusts. A number of miners live to a ripe old age even when clinical manifestations of disease are apparent. Obviously, consideration should be given to the question whether the average duration of life among men exposed to large quantities of dusts liberated in hard-coal mining operations differs from that of men not so exposed.

Studies of mortality of anthracite miners in the past have been rather inconclusive, because death rates could not be computed on account of lack of knowledge of the number of miners among whom the deaths occurred. Another handicap was the inadequate occupational histories of the decedents. Lacking the necessary data for the computation of mortality rates, students of the subject computed the proportionate mortality, i. e., the percentage of deaths from any given cause. On this basis an unusually low proportion of deaths from pulmonary tuberculosis and certain other respiratory diseases appeared to occur among hard-coal miners. The conclusion was drawn that anthracite miners were unusually immune to tuberculosis and certain other diseases to which dust may predispose. A later study of mortality in the Wilkes-Barre coal field, however, disclosed the fact that about 39 percent of the deaths among miners at ages 15 to 65 were due to accidents as compared with approximately 10 percent of the deaths of nonminers at these ages (*22*). Such a large proportion of miners' deaths from accidents manifestly produced relatively small percentages for other causes, since the sum of the percentages in proportionate mortality is 100. An excessive death rate from any given cause might thus be obscured by the inequality in mortality from accidents. When the deaths due to accidents and to certain diseases showing an abnormally high proportion of deaths among hard-coal miners were deducted, it was found that the percentage of deaths from respiratory tuberculosis was 1.4 times the corresponding percentage for male decedents who had been engaged in industries other than mining in the Wilkes-Barre area. The proportionate mortality figures (after deduction of deaths from accidents) also showed an abnormally high percentage of deaths from influenza and pneumonia among anthracite coal mining employees. The proportion of miners' deaths recorded as due to pneumoconiosis was found to be 10 times the percentage among male decedents who had been employed in industries other than mining in the Wilkes-Barre area.

Although these results appeared to be significant, in the absence of actual death rates there was no proof that anthracite coal mining was associated with an excessive respiratory disease mortality.

Some excess of tuberculosis and perhaps other respiratory diseases was to be expected on account of the rock drilling operations known to be hazardous to health, but the important question whether the much larger number of men working at the coal face tended to die prematurely from diseases of the respiratory system could not be answered on account of the lack of occupational histories for living employees of the industry and the large number of vague statements regarding the occupations of the decedents recorded on the death certificates.

For these reasons when a study of lung pathology among hard-coal workers was started in the summer of 1933, an attempt was made to obtain data which would afford mortality rates. Each worker examined was asked whether his father was alive; if dead, the cause of death; his father's occupations and periods of time employed in each; and other pertinent facts. It was recognized that such procedure constituted an unorthodox method of obtaining mortality data, but in the anthracite coal fields the son so often follows in the occupational footsteps of his father that it seemed possible to obtain a sufficient number of records for a comparison of death rates in mining with nonmining pursuits in this region.

The number of years of life under observation used as the divisor in obtaining mortality rates was computed for each father from age 30 to his present age if living; or if deceased, to his age at death. These years of life were counted separately for each decade, and the father's age and length of service at the midpoint of each 10-year period were computed so that the trend in miners' mortality could be observed.

On account of the nature of the records, certain technical points had to be kept in mind. For example, quite often several sons reported on the same father, but a careful check was made to avoid duplicated records, especially in the deaths.

The number of lives thus covered totaled 1,059. This number is much smaller than the number of men interviewed, largely because many records had to be discarded on account of the inadequacy of the occupational histories obtained on the fathers, or because the father had never lived in the United States.

Out of a total of 446 deaths due to sickness or nonindustrial accidents among the 1,059 lives covered, 152 or approximately one-third were checked with the official death certificates filed in the Bureau of Vital Statistics of the Pennsylvania Department of Health for the purpose of ascertaining the extent to which the causes of death were accurately reported by the sons. The son's statement was usually in agreement with the physician's report, especially as regards diseases of the respiratory system with which this study is primarily concerned. Occasionally the nature of the disease as reported by the son differed

widely from the statement on the death certificate. Considering the sample as a whole, however, it was found that the number of deaths from respiratory disease as reported by the sons was 56; the mortality certificates showed 54 deaths in which some respiratory disease was recorded as the primary cause of death.

TABLE 45.—*Comparison of the causes of death of 152 anthracite coal workers as reported by the son, and as given on the death certificate*

	Reported by the son	Death certificates	
		Primary cause of death [1]	Either primary or contributory cause of death
All causes of death	152	152	205
Respiratory diseases	56	54	75
Tuberculosis	1	15	15
Miners' asthma [2]	18	5	12
Influenza or pneumonia	30	29	33
Asthma or bronchitis	4	3	7
Other respiratory diseases	3	2	8
Nonrespiratory diseases	54	81	113
Heart or other circulatory disease	28	40	65
Other nonrespiratory diseases	26	41	48
Hard coal mine accidents	11	10	10
Other accidents	7	6	6
Cause of death unknown	24	1	1

[1] In accordance with the Manual of Joint Causes of Death, Vital Statistics Division, Bureau of the Census, Washington.
[2] Anthracosis, pneumoconiosis.

The sons rarely reported tuberculosis as a cause of death, apparently regarding almost all such cases as miners' asthma; but when the two are added it is found that the sons reported 19 in comparison with 20 on the death certificates. When miners' asthma as a contributory cause of death is considered, the number of death certificates showing either tuberculosis or miners' asthma totaled 27 in the group of 152 records. For influenza and pneumonia, and for other respiratory diseases as a group, the totals in the two sets of data were almost the same.

The number of deaths used in computing the mortality rates shown in tables 47 to 50 are somewhat greater than those actually reported as due to the diseases specified, on account of an allocation of the deaths for which the cause was not known to the son. Some sort of allocation or adjustment was necessitated by the fact that relatively more deaths of unknown cause occurred in the control groups than in the dusty occupations of anthracite mining. The basis for allocating the "unknowns" was the percentage of deaths from respiratory disease among white males age 25 and over in the registration area of the United States in 1925. In that year and in certain other epidemic-free years, about one-sixth of the deaths in this sex and age class were due to respiratory diseases. The proportion due to influenza and

pneumonia was about 8½ percent, and to other respiratory diseases as a group, about 8 percent. Accordingly, these percentages were used in allocating deaths in which the informant did not know the cause.

1. MORTALITY FROM SICKNESS AND NONINDUSTRIAL ACCIDENT

The highest death rate from disease (including nonindustrial accidents) occurred among the miners' fathers who had worked steadily for more than 5 years at rock drilling in anthracite mines. The second highest mortality rate occurred among the miners and mine laborers at the face. Their rate was 19.1 deaths per 1,000 man-years,[21] as compared with 11.7 among men in the nonmining occupations of the industry exclusive of rock drillers. All mortality rates were adjusted to eliminate age differences in the groups under comparison.

TABLE 46.—*Mortality from sickness and nonindustrial accidents among the fathers of anthracite coal workers interviewed*

Pursuits of the fathers of anthracite workers interviewed [1]	Adjusted death rate [2]	Crude death rate [3]	Number of deaths	Number of years of life included in the record
1. Industries other than anthracite mining	16.6	15.8	164	10,375
2. Nonmining occupations in anthracite coal industry	11.7	11.3	92	8,158
3. Miners and mine laborers	19.1	15.2	164	10,799
4. Rock drillers in anthracite mines	25.9	23.1	26	1,126

[1] Group 1 includes men who had spent less than 5 years in the anthracite mining industry, but no one who had ever worked for any appreciable period as a rock driller, or in any other dusty trade known to be hazardous to health. Group 2 includes workers at the surface of anthracite mines, but no one who had spent more than 5 years in a dusty breaker; also underground workers other than miners, mine laborers, and rock drillers; and men who had both mined and engaged in other underground work if the mining had not exceeded 5 years. Group 3 includes breaker house employees in 1 of the 3 mines under study on account of the large amount of dust generated there. Group 4 covers persons who had spent 5 years or more steadily at rock drilling. Men who had retired from coal mining 10 or more years prior to the time of the study were not included in the table.

[2] To eliminate differences due to the age distribution of the groups under consideration.

[3] Annual number of deaths per 1,000 men at ages 25 and over.

Analysis for each of the three mines under study showed consistent results. In each mine the mortality of miners and mine laborers at the coal face was greater than among persons engaged in industries other than mining. In the relatively nondusty occupations of the anthracite industry, disease mortality occurred at a comparatively low rate in each of the mines.

2. MORTALITY FROM RESPIRATORY DISEASES

Mortality from respiratory diseases was much greater among men engaged in work at the coal face than among persons in the nonmining occupations of the industry, exclusive of rock drillers. The greater mortality from these diseases among rock workers was also found to be significant statistically in spite of the small number of lives under review in this group. Among underground workers other

[21] A man-year is the equivalent of 1 man under observation for 1 year. The number of man-years or years of life under observation constitutes the divisor in the computation of mortality rates.

139428—36——8

than miners, mine laborers, and rock workers, the respiratory disease mortality rate was relatively low, indicating that underground work per se did not predispose to fatal attacks of respiratory disease.

TABLE 47.—*Mortality from respiratory diseases among the fathers of anthracite coal workers interviewed*

Pursuits of the fathers of anthracite workers interviewed [1]	Death rate per 100,000 men	Number of deaths	
		Reported by sons as due to respiratory disease	Including those allocated from the group in which the cause of death was not known to the son [2]
1. Industries other than anthracite mining	337	25	35
2. Nonmining occupations in anthracite coal industry	417	31	34
3. Miners and mine laborers	852	87	92
4. Rock drillers in anthracite mines	1,687	19	19

[1] See footnote 1 of table 46.

[2] Deaths for which the cause was not known to the son were allocated to the respiratory disease group in accordance with the proportion found among white male decedents age 25 and over in the registration States of 1920 during the year 1925.

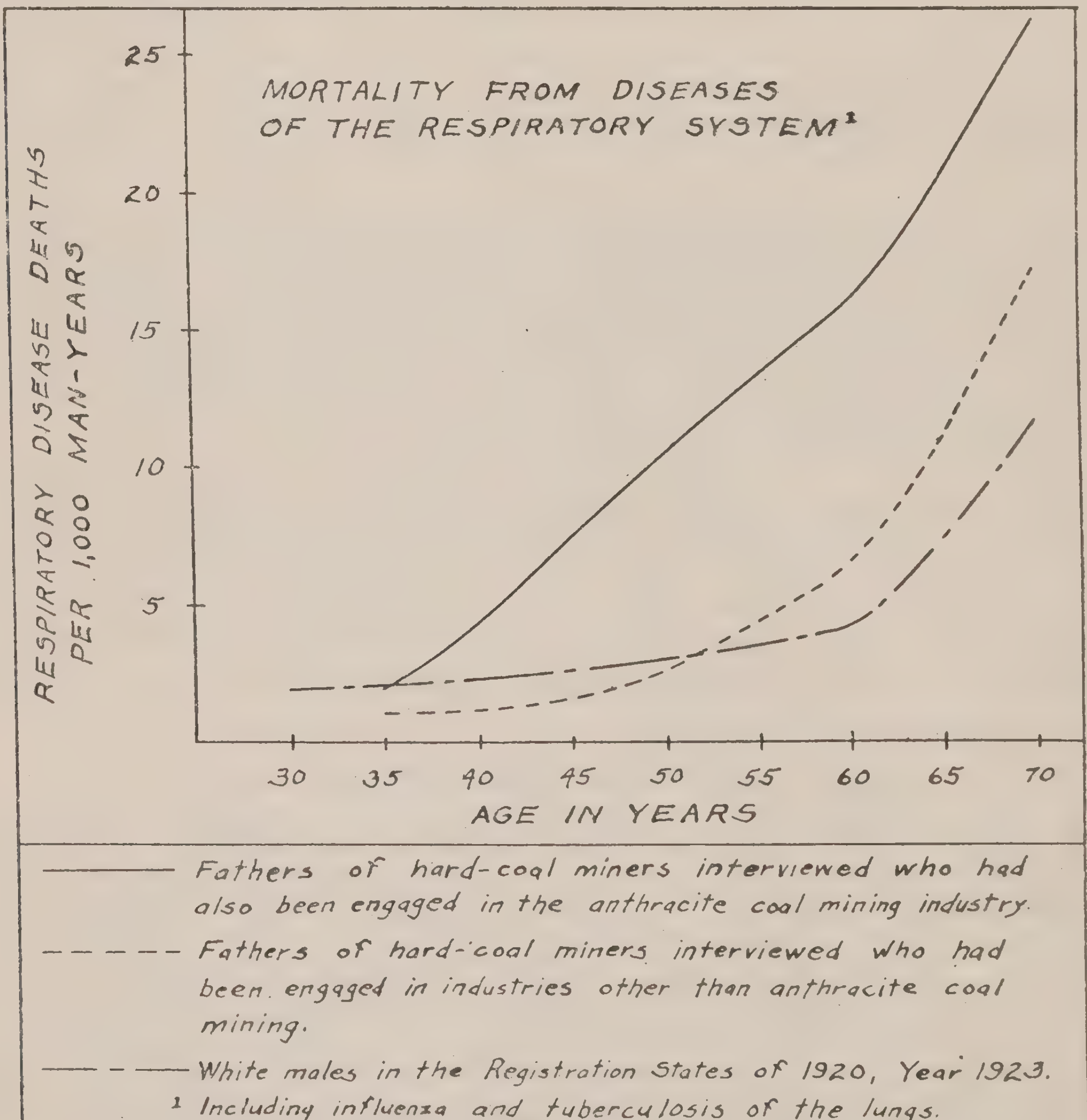


FIGURE 30.—Mortality by age from diseases of the respiratory system [1] among the fathers of hard-coal miners interviewed.

The rate of death from diseases of the respiratory system at ages below 40 or 45 was found to be no greater among the fathers of the group of hard-coal workers interviewed who had also worked in anthracite than among the fathers who had been employed in other industries, or among white males in the registration States of 1920 during the year 1923.[22] After age 40 or 45, however, the respiratory disease mortality of the anthracite workers increased much more rapidly than that of the other 2 groups, the rate at ages 45 to 54 being about 10 per 1,000 man-years as compared with less than 3 in either of the 2 other groups. At ages 55 to 64 about 16 deaths from respiratory disease occurred per 1,000 man-years among anthracite workers in contrast with a rate of 6 among the fathers of living hard-coal workers who had been engaged in industries other than anthracite mining, and with a rate of 4 among white males in the general population of the country. If persons working at the coal face instead of all anthracite workers had been considered, it is obvious that the contrast with the mortality experience of the general population would have been even greater.

TABLE 48.—*Mortality by age from respiratory diseases among the fathers of anthracite-coal mining employees interviewed*

Male groups	Ages 25 and over	25–34	35–44	45–54	55–64	65 and over
RESPIRATORY DISEASE DEATH RATES PER 1,000 MAN-YEARS						
Fathers of hard-coal workers interviewed who had also been engaged in the anthracite industry	7.22	1.91		10.30	15.85	26.36
Fathers of hard-coal workers interviewed who had been engaged in industries other than anthracite mining	3.37	0.91		2.42	6.26	17.26
White males, registration States of 1920 for year 1923	3.32	1.66	2.25	2.79	4.13	11.80
NUMBER OF DEATHS FROM RESPIRATORY DISEASE[1]						
Fathers of hard-coal workers interviewed who had also been engaged in the anthracite industry	145	22		48	42	33
Fathers of hard-coal workers interviewed who had been engaged in industries other than anthracite mining	35	5		6	10	14
Male whites, registration States of 1920, for year 1923	74,236	11,310	13,255	12,809	12,250	24,612
NUMBER OF MAN-YEARS INCLUDED IN THE RECORD						
Fathers of hard-coal workers interviewed who had also been engaged in the anthracite industry	20,083	11,522		4,659	2,650	1,252
Fathers of hard-coal workers interviewed who had been engaged in industries other than anthracite mining	10,375	5,487		2,481	1,596	811
Male whites, registration States of 1920, for year 1923	22,352,891	6,803,915	5,910,623	4,594,343	2,960,671	2,083,339

[1] Including influenza and tuberculosis of the lungs.

[22] The mortality rate from all respiratory diseases among white males in the registration States was not available over a series of years. The year 1923 was selected because the respiratory disease mortality rate in that year appeared to represent fairly well the average mortality from these diseases over a number of years.

3. MORTALITY FROM INFLUENZA AND PNEUMONIA

In table 49 a high rate of mortality from influenza and pneumonia is indicated for miners and their helpers. The difference in this rate and the average rate for the two control groups (groups 1 and 2) was found to be 3.1 times the probable error of the difference in the rates. Although this result is not definitely significant, the weight of evidence inclines toward substantiation of an earlier study based on larger numbers which showed unusual susceptibility on the part of anthracite miners to fatal attacks of influenza and pneumonia (*22*). There was no greater mortality from influenza and pneumonia among men in the nonmining occupations underground, with the exception of rock drillers, than among men in industries other than anthracite mining.

TABLE 49.—*Mortality from influenza and pneumonia among the fathers of anthracite-coal workers interviewed*

Pursuits of the fathers of anthracite workers interviewed [1]	Death rate per 100,000 men	Number of deaths	
		Reported by the sons	Including those allocated from the group for which the cause of death was not known to the son [2]
1. Industries other than anthracite mining	241	20	25
2. Nonmining occupations in anthracite-coal industry	245	18	20
3. Miners and mine laborers	389	39	42
4. Rock drillers in anthracite mines	355	4	4

[1] See footnote 1 of table 46.
[2] Deaths for which the cause was unknown to the son were allocated to influenza and pneumonia in accordance with the percentage of such deaths among white male decedents age 25 and over in the registration States of 1920, during the year 1925.

4. MORTALITY FROM ALL RESPIRATORY DISEASES EXCEPT INFLUENZA AND PNEUMONIA

The diseases in this group are of particular interest because they include pulmonary tuberculosis, bronchitis, emphysema, pneumoconiosis, and certain other respiratory diseases to which dust exposure may predispose. In the tabulation covering these diseases the four occupational groups arrayed themselves in the same order as appeared in the mortality from all respiratory diseases combined, but the differences in the death rates were wider than those shown for all respiratory diseases. The miners' mortality from respiratory diseases other than influenza and pneumonia was about three and one-half times the average rate of death from these diseases in the two control groups, and in rock drilling about 10 times as great. These differences are so wide that statistical significance may be demonstrated even with the small number of lives under observation. The odds were found to be overwhelming against chance as a producer of the differences found in the mortality from pulmonary tuberculosis, bronchitis, pleurisy, emphysema, pneumoconiosis, and certain other respiratory diseases as a group.

TABLE 50.—*Mortality from all respiratory diseases except influenza and pneumonia among the fathers of anthracite coal workers interviewed*

Pursuits of the fathers of anthracite workers interviewed [1]	Death rate per 100,000 men	Number of deaths	
		Reported by the sons	Including those allocated from the group in which the cause of death was unknown to the son [2]
1. Industries other than anthracite mining	96	5	10
2. Nonmining occupations in anthracite coal industry	172	13	14
3. Miners and mine laborers	463	48	50
4. Rock drillers in anthracite mines	1,332	15	15

[1] See footnote 1 of table 46.
[2] Deaths for which the cause was unknown to the son were apportioned to this disease group in accordance with the percentage of such deaths among white male decedents age 25 and over in the registration States of 1920 during the year 1925.

5. MORTALITY ACCORDING TO LENGTH OF SERVICE

On account of the difficulty of obtaining exact information from the sons as to the length of time that the father had been employed in different occupations, mortality rates are presented for only two periods of service, viz: 20 to 29 years, and 30 or more years. Death rates were computed according to these periods of service for the age group 45 to 64 because it afforded the largest amount of data on persons with the longer service. One may see from table 51 that miners and mine laborers experienced a higher rate of mortality from disease after 30 years' service than did the men in the nonmining occupations of the industry exclusive of rock drillers. This difference in mortality was 3.4 times the probable error of the difference. Stated in another way, the odds were 45 to 1 against chance fluctuation incident to small numbers as the cause of the indicated difference in mortality. Although these odds are not great enough to eliminate the possibility of chance as a factor, it appears that 30 or more years of work at the coal face is likely to involve greater risk of dying prematurely from disease than does the same length of employment in other underground occupations, rock drilling excepted, or in work at the surface.

TABLE 51.—*Mortality from sickness and nonindustrial accidents according to time spent in the anthracite mining industry by men at ages 45 to 64*

Length of service	Death rate per 1,000 men			Number of deaths			Number of years of life		
	Miners and their helpers [1]	Nonmining occupations in anthracite mining [1]	Industries other than anthracite mining [1]	Miners and their helpers [1]	Nonmining occupations in anthracite mining [1]	Industries other than anthracite mining [1]	Miners and their helpers [1]	Nonmining occupations in anthracite mining [1]	Industries other than anthracite mining [1]
All lengths of service	24.9	15.5	19.1	94	48	78	3,780	3,099	4,077
20 to 29 years	20.1	14.1	--------	25	10	--------	1,242	711	--------
30 years and over	30.0	18.2	--------	57	26	--------	1,901	1,426	--------

[1] See footnote 1 of table 46.

6. MORTALITY BY DECADES

Is disease mortality among miners in the anthracite region of Pennsylvania increasing or decreasing? An answer to this question was attempted by computing death rates according to decade. In the earlier decades the fathers of the miners interviewed were all young men among whom few deaths from disease occurred. In recent decades the group was largely composed of old men. On account of the wide differences in age distribution and the small number of deaths and years of life under observation in the earlier periods, it is doubtful that the adjusted or standardized rates for the decades prior to 1905 possess sufficient accuracy to be of any value. For this reason they have been omitted in table 52. In the three decades since 1905 the numbers are obviously too small to give significant meaning to the indicated increases in the death rate, but the results at least raise doubt whether any improvement has occurred in disease mortality among miners and their helpers during the last three decades.

TABLE 52.—*Mortality from sickness and nonindustrial accidents among anthracite coal miners and their helpers, by decades*

Decades	Annual death rate adjusted [1]	Number of deaths	Number of years of life included in the record
1905–14	17.6	35	2,637
1915–24	24.1	55	2,377
1925–33	26.8	58	1,409

[1] To eliminate differences in the age distribution of the men under comparison.

7. SUMMARY OF MORTALITY

Incident to the physical examination of employees of the anthracite coal mining industry made by the United States Public Health Service, each examinee was queried in regard to the occupations which his father had pursued, and if his father had died, the cause of death. Statements concerning cause of death were checked with the official death certificates filed in the Bureau of Vital Statistics of the Pennsylvania Department of Health. Death rates based on the information thus obtained corroborated earlier studies of proportionate mortality in which the number of deaths from respiratory diseases appeared to be excessive among men in the anthracite industry. The present study discloses the important point that the high respiratory disease mortality was not due entirely to the rock drillers, an occupation known to be hazardous to health, but in part to those engaged in work at the coal face. Among both miners and rock drillers the mortality rates were abnormally high from

influenza and pneumonia as well as from respiratory diseases other than influenza and pneumonia. The fathers who had spent most of their lives in the relatively nondusty occupations of the industry or who had mined hard coal for less than 5 years experienced only normal or average mortality from diseases of the respiratory system.

REFERENCES

(1) Occupational Disease Legislation. A Report by the Pennsylvania Commission on Compensation for Occupational Diseases, to Governor Pinchot, Harrisburg, Pa., 1933, p. 7.

(2) Greenburg, Leonard, and Bloomfield, J. J. The Impinger Dust Sampling Apparatus as Used by the United States Public Health Service. Public Health Reports, vol. 47, no. 12, Mar. 18, 1932, pp. 654–675.

(3) Knopf, Adolf. The Quantitative Determination of Quartz (Free Silica) in Dusts. Public Health Reports, vol. 48, no. 8, Feb. 24, 1933, pp. 183–190.

(4) Bloomfield, J. J. Size Frequency of Industrial Dusts. Public Health Reports, vol. 48, no. 32, Aug. 11, 1933, pp. 961–968.

(5) Owens, J. S. Jet Dust Counting Apparatus. Jour. Industrial Hygiene, vol. 4, no. 12, April 1923.

(6) Chamot, E. M., and Mason, C. W. Handbook of Chemical Microscopy. John Wiley and Sons, Inc. New York, 1930, p. 402.

(7) Houghten, F. C., Teague, W. W., Miller, W. E., and Yant, W. P. Heat and Moisture Losses from Men at Work and Application to Air Conditioning Problems. Heating, Piping, and Air Conditioning for June 1931, p. 493.

(8) Brundage, Dean K., and Frasier, Elizabeth S. The Health of Workers in Dusty Trades. III. Exposure to Dust in Coal Mining. Public Health Bulletin No. 208, July 1933.

(9) Hatch, Theodore, Fehnel, J. Wm., Warren, Henry, and Kelley, George S. Control of the Silicosis Hazard in the Hard Rock Industries. IV. Application of the Kelley Trap to Underground Drilling Operations. Jour. Industrial Hyg., vol. 15, No. 1, Jan. 1933, pp. 41–56.

(10) Smith, Adelaide Ross. Silicosis among Rock Drillers, Blasters, and Excavators in New York City. Jour. Industrial Hyg., vol. 11, No. 12, Feb. 1929, pp. 39–69.

(11) Russell, A. E., Britten, R. H., Thompson, L. R., and Bloomfield, J. J. The Health of Workers in Dusty Trades. II. Exposure to Siliceous Dust (Granite Industry). Public Health Bulletin No. 187 (1929).

(12) Forbes, J. J., and Emery, Alden H. Sources of Dust in Coal Mines. Reports of Investigations, Department of Commerce, Bureau of Mines, Serial No. 2793, Feb. 1927.

(13) King, Earl J. and Dolan, Marjorie. Silicosis and the Metabolism of Silica. Canadian Medical Association Journal, vol. 31, No. 1, July 1934, pp. 21–26.

(14) Cummins, S. L. and Sladden, A. F. Coal-Miner's Lung; Investigation into Anthracotic Lungs of Coal Miners in South Wales. Jour. of Path. and Bacteriol., 33, Oct. 1930, pp. 1095–1132.

(15) Miller, J. W., Sayers, R. R., and Yant, W. P. Response of Peritoneal Tissue to Dusts Introduced as Foreign Bodies. Jour. American Med. Ass'n., 103, Sept. 22, 1934, pp. 907–911.

(16) King, E. J., Stantial, H., and Dolan, M. Biochemistry of Silicic Acid. Presence of Silica in Tissues. Biochemical Jour., vol. 27, 1933, pp. 1002–1006.

(17) McNally, W. D. Silicon Dioxide Content of Lungs in Health and Disease. Jour. American Med. Ass'n., 101, Aug. 19, 1933, pp. 584–587.

(18) Badham, C., and Taylor, H. B. Coal Miner's Lung: Preliminary Account of Chemical Analysis and Pathology of Lungs of Coal Miners in New South Wales. Med. Jour. Australia, 1, Apr. 29, 1933, pp. 511–524.

(19) National Tuberculosis Association: Framingham Community Health and Tuberculosis Demonstration. Framingham Monograph No. 10, July 1924, p. 69.

(20) Sydenstricker, Edgar, and Britten, R. H. The Physical Impairments of Adult Life. Amer. J. of Hygiene, vol. XI, no. 1, Jan. 1930, pp. 89 and 100.

(21) Britten, R. H., and Thompson, L. R. A Health Study of Ten Thousand Male Industrial Workers. Public Health Bulletin No. 162. Government Printing Office, Washington, 1926, p. 161.

(22) Brundage, Dean K. The Mortality of Coal Miners. Public Health Bulletin No. 210. Government Printing Office, Washington, 1933, p. 2.

O